LR *Technical Association*

FPSO Classification Accounting for the Variables

by G. Alford

Lloyd's Register

Paper No **1**
Session 1996–1997

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Discussion on the Paper

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Hon. Sec. A. J. Williamson
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FPSO Classification Accounting for the Variables

by G. Alford

DISCUSSION

From Mr T R Welham

There are currently in excess of 20 steel monohull FPSOs planned, or in operation, world-wide. This contrasts with the 2 concrete monohull units which are in operation in relatively benign environments.

Various companies are proposing the use of concrete monohulls, but to date these have been relatively unsuccessful. Does the Author consider the concrete monohull to be a viable alternative to steel for fixed floating units operating in harsh environments?

To Mr T R Welham

I have no doubts that a concrete FPSO can be successfully designed to operate in most regions of the world. Studies carried out for the BP Schiehallean project and more recently Petro-Canada's Terra Nova field have confirmed the concept to be acceptable.

My own thoughts on the reasons for the greater use of steel construction are:

i) Oil industry's traditional conservatism to new technology applications,
ii) Availability of detailed classification rules,
iii) Lower costs and greater confidence in meeting delivery schedules,
iv) Residual value and the feasibility of re-use at the end of the field life.

From Mr M H Heywood

In relation to fixed offshore platforms it was historically the practice to locate the accommodation immediately adjacent to the process. Subsequent to Piper Alpha, a lot of money and effort was expended to isolate personnel from the risks associated with the process. This was achieved by the adoption of the Not Normally Manned concept and by the use of separate accommodation platforms.

The basic layout of the FPSO again places accommodation adjacent to the process, although the risk and consequences are slightly different for bow as opposed to stern accommodation.

In view of the increasing requirement throughout the world to adopt the Safety Case approach and to reduce the risks to personnel to As Low As Reasonably Practical (ALARP), is it possible that the current continuous manning strategy of FPSOs could change?

To Mr M H Heywood

Traditionally, the large fixed platforms were designed to incorporate a large manning capability so as to be able to carry out multiple functions, preferably without incurring the cost associated with an additional floatel.

The FPSO has never been used to carry out all these functions and manning levels have subsequently been relatively modest.

The current techniques of Quantified Risk Assessment (QRA) are now well developed and under the current goal setting regime, designs are produced whereby risk has been reduced to a level deemed acceptable by the principles of ALARP. With the use of QRA it is being demonstrated that the risks to personnel are acceptable. Consequently, due to the nature of the manning requirements of the FPSO, I would not expect the adoption of the Not Normally Manned concept.

From Mr C R Labrie

Verification requirements are clearly goal setting while LR's Classification Rules and Regulations are prescriptive.

Many non-UK clients depend on the design guidance provided by prescriptive rules. However, the Health and Safety Executive (HSE) has stated that the prescriptive regulations alone do not provide adequate coverage for the fire and safety aspects of topsides.

Should we, therefore, follow the HSE's example and produce goal setting regulations for the fire and safety aspects of topsides, and if so, how could we impose such regulations on nations who do not have the UK's offshore experience?

To Mr C R Labrie

It is unlikely, at the present time, that the Classification Rules could be goal setting. There are a number of strong reasons why this would be the case:

i) The majority of countries in the world use prescriptive rules and as yet have little experience in developing a goal setting approach to safety.

ii) Secondly, where a company is selected to build such an installation, the prescriptive class rules provide a basis for the contractual standard to be delivered.

However, in my opinion, there could be a move towards a more goal setting approach to classification in the future, especially in relation to the safety and layout of topside facilities.

From Mr D W Woodcraft

Does Lloyd's Register make it clear to the client that one of the services we can offer is a large amount of data, held within the Marine Division Database, which can be used in reliability studies or fire risk analyses?

Amongst the many clients to whom we have already supplied data are AMEC, Maersk Offshore and BP International.

To Mr D W Woodcraft

It is clearly important that our clients are fully aware of the range of services that LR can offer.

Most of the studies referred to involve the Croydon based System Integrity & Risk Management department, who we understand are fully aware of the point you make.

Offshore Services do not normally become involved in this particular work, however, we are keen to ensure that all our clients are advised of our services. In this respect we would be pleased to include an appropriate fact sheet in our FPSO Capability Document.

From Mr W H W Chan

Thank you for a very informative and well presented paper.

It is not mandatory for FPSOs to remain in class to operate. When a vessel is not classed, LR's jurisdiction, if any, would be confined within the scope of 'Certificate of Fitness' for example. Under such circumstances, how can Lloyd's Register effectively enforce the class requirements with regard to survey and condition monitoring?

To Mr W H W Chan

Ongoing survey and monitoring of FPSO installations is recognised as a key issue with respect to long term integrity and safety.

An approved survey schedule is required for Certificate of Fitness/Verification and the requirements of LR Rules would be considered to offer an appropriate standard. Alternative proposals could be considered provided these include all appropriate components in a rational manner.

It is clear from those schedules currently planned and in place, that operators continue to demonstrate their commitment to ensuring that safety of the installation will not be compromised by inadequate survey and monitoring.

From Miss K Hadden

Has the in-service survey schedule (and particularly that relating to the machinery) proposed by LR for classification of FPSOs been accepted by any operators yet?

To Miss K Hadden

This question is on a similar theme to Mr Chan's.

All FPSO installations classed or certified by LR are subject to a scheme of periodic surveys in accordance with LR Rules and national regulations.

A survey schedule will be agreed for each installation. Detailed schedules will be project specific and developed to suit installation parameters and operational considerations. For example, the UK verification scheme in place for Bluewater's FPSO operating at the Fife field in the North Sea differs from that developed for Modec's Maui-B installation which is based on classification rules and would be acceptable to the New Zealand authorities.

FPSO Classification Accounting for the Variables



by G. Alford

In 1954, George Alford started work with the Burntisland Shipbuilding Co.Ltd. where he was mainly involved with the structural design of various types of ships. He joined Lloyd's Register in 1966 and initially worked on ship structural plan approval and also on offshore projects in the then Ship Research Department. In 1971 he became part of the newly formed Ocean Engineering Department where in 1985 he was appointed Principal Surveyor. George Alford is now Head of the Ocean Engineering Department in the Offshore Group in London which deals with all types of fixed and floating installations.

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Synopsis

FPSO contracts usually involve a number of different contractors for the supply of major components of the vessel, eg. the shipyard, mooring system contractor and the manufacturer of the process units. It is often the case that these activities are carried out in different locations and countries. It is therefore essential that a uniform and acceptable standard is implemented and also that the interfaces between the various components are properly addressed. Classification is a system which can successfully provide these services.

This Paper deals with technical and regulatory issues regarded as important to designers and operators and which are based on experience gained from projects classed world-wide.

The need for early dialogue is discussed and how close co-operation, with Lloyd's Register (LR) in an integrated role with the project team, can make a positive contribution to the design development, project efficiency and possible cost savings.

Requirements for strength and fatigue, important for effective reliability in service and the key issues of position mooring and process, are covered.

Some considerations concerning conversions are raised and on-site survey is recognised as being essential to the economic success and safe operation of the installation.

LR's classification rules for floating production installations can offer class notations for the complete installation which can include the subsea system if required.

1 Introduction

The changing nature of today's international oil industry is clearly reflected by the increasing use of floating production systems world-wide. The installations recently Classed/Certified by LR are shown in Table 1.

Floating Production, Storage and Offloading Units (FPSOs) provide a number of practical advantages compared with fixed installations. They are straightforward to build, based on conventional shipbuilding technology, and expensive offshore work is kept to a minimum as most of the construction, hook-up and commissioning can be completed inshore at significantly less cost. FPSOs have the ability to handle heavy payloads and to add equipment incrementally to fit production and reservoir changes as well as offering storage and offloading facilities. They are easier to install and decommission and can be used again in other fields. It is also the case that current technical developments favour the use of FPSOs for larger fields and in deep water operations.

With oil prices likely to remain low, many field developments will only go ahead with reduced capital expenditure. The industry is now geared up to provide lower cost projects but will the safety objectives be fulfilled in this starker economic environment? Classification can fulfil the requirements of safety and the new "goal setting" regulations now in place by many national authorities.

FPSOs are integrated production systems which are made up from diverse types of components to enable them to carry out operations. Classification, therefore, must be able to address the large number of variables which are shown in Figure 1 and include:

- Structures/conversions
- Mooring systems
- Process plant
- Safety systems
- Stability
- Inspection/maintenance on site

Table 1

Field	Country	Operator	Installed	Description
Griffin	Australia	B.H.P. Petroleum	1993	New Build
Dragon	Vietnam	Petrochim/Vietsovpetro	1994	Conversion
Fife	U.K.	Amerada Hess/Bluewater	1995	Conversion
Barracuda	Brazil	Petrobras	1995	Conversion
Liverpool Bay	U.K.	B.H.P. (Hamilton Oil)	1996	New Build
Maui B	Captain	Shell Todd	1996	Conversion
Captain	U.K.	Texaco	1996	New Build
CNS (Teal)	U.K.	Shell	1996	New Build
MacCulloch	U.K.	SLP/Maersk	1997	Conversion
Schiehallion	U.K.	Atlantic Frontier Alliance	1997	New Build
Durward/Dauntless	U.K.	Amerada Hess/Bluewater	1997	New Build
Curlew	U.K.	Shell/MAS Alliance	1997	Conversion
Galley	U.K.	Texaco/ODCC	1998	Conversion

Alliance contracting is becoming more widespread as oil companies seek to share responsibilities with contractors and jointly improve field development economics. As a result, major components of FPSOs can be manufactured in different locations around the world to meet contract completion schedules, eg. the FPSO hull can be built in Japan, the process modules in Holland and the final installation in the UK. Because of their international set-up, classification societies offer a total service including survey, inspection, plan approval and long-term integrity management. The global network of LR offices provides co-ordination and 'on-the-spot' support for design appraisal and site construction. It is difficult to think of another comparable system which can provide industry with similar impartial services on a world-wide basis.

Classification has played an important role in the marine industry and can also provide FPSO operators with standards which are in line with their needs for "fitness for purpose" and which also fulfil the level of safety required by the authorities.

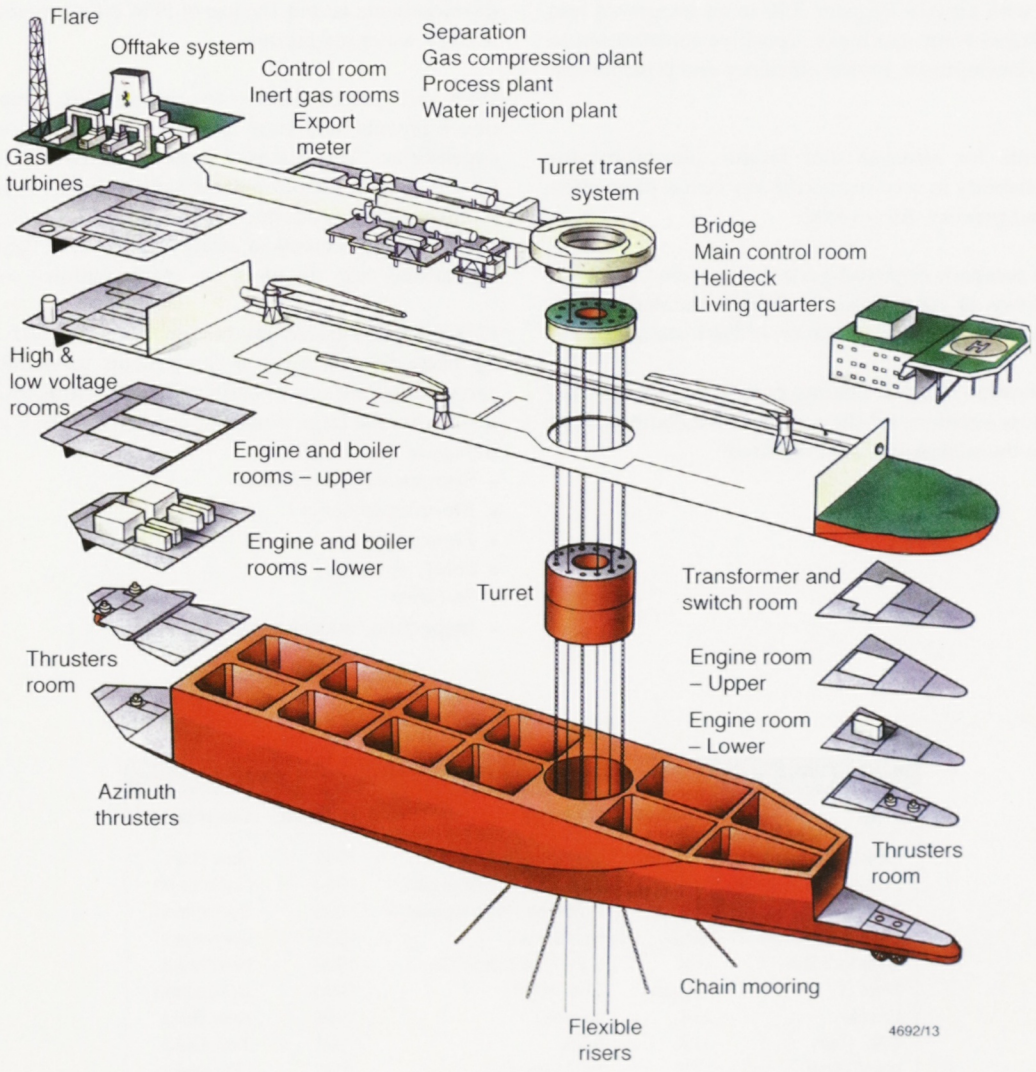


Figure 1

2 Regulations

To operate within the territorial waters of most countries, an FPSO will require to comply with all the appropriate regulations. These will include classification rules, national authority standards, statutory regulations and relevant codes and standards.

2.1 Verification Regulations

New verification regulations are now in force in the UK to replace the existing certification scheme. The key change is the requirement that systems identified as being safety critical will have to be subjected to a verification scheme throughout the lifecycle of the development.

It is likely that other countries will adopt similar schemes. Norway is currently introducing this approach to all new field developments.

The new UK regulations make the operator responsible for two important issues:

(i) Set and define the role of non-prescriptive safety goals which are particular to the installation and establish the performance standards required by the project to achieve these goals.

(ii) Establish a verification scheme (employing an independent party) which audits all the critical issues affecting the design, construction, installation, and operation.

To enable compliance with the requirements of the verification scheme, the new regulations have identified the following important points:

- Independence and impartiality.
  The verification work can be only be undertaken by a competent body which is not involved in any design, manufacturing or management activity of the development.
- Completeness and quality assurance.
  The verification work should provide a full audit to cover examination of any design, specification, certificate and document and also include the fabrication, installation and operation activities required to monitor the quality of the critical systems of the installation.
- Mitigation and prevention.
  The verification scheme should identify design errors with the potential to cause a major accident and initiate any appropriate preventive action.

Classification fulfils all these requirements and caters for the lifecycle of the development. It is concerned with the safety integrity and quality of marine structures and also provides compliance with the verification regulations. The classification society's own rules, are regularly updated to take account of the developments arising from service experience, new design techniques and material and construction methods. In addition, the classification society's status fulfils the requirements of an independent and impartial verification body.

Where there are no national verification requirements, classification rules can provide the independent standards and prescription guidance acceptable to government authorities, insurers and other interested parties world-wide. Lloyd's Register's classification is recognised throughout the world and is formally accepted by the Governments of Australia, Canada, the Peoples Republic of China, Denmark, Indonesia, the Irish Republic, the Netherlands, New Zealand, Norway, Papua New Guinea, the USA and the UK.

LR has also worked with and assisted various governments in formulating regulations or selecting applicable standards. In Vietnam, LR and the Vietnamese Register of Shipping (VIRES) have agreed a joint venture which permits LR to provide a full range of technical services associated with offshore and industrial projects.

2.2 Statutory Regulations

The extent to which MARPOL and SOLAS regulations are to be applied will be determined by the coastal state and also the flag state, and it is clearly important that the owners discuss their proposals with the appropriate bodies at the earliest opportunity.

IMO have decided that tankers which are used solely for the storage and production of oil, and are moored in a fixed location, are not required to have double hulled construction unless specified by the coastal state. The proposed arrangements (including for example a single bottom hull, the layout of storage and ballast tanks etc.) should, therefore, be clarified early in the design phase with the national administration.

If the FPSO is registered with a flag administration, it is likely that it will have to comply with MARPOL Regulation 25 for damage stability and seagoing ship intact stability criteria. This will satisfy the requirements of most national authorities. A load line may not be required whilst the vessel is moored on station but could be required for the delivery voyage or when in transit if these voyages are manned.

2.3 Class Rules

LR Rules for Floating Production Installations includes sections covering:

- Hull and turret structure.
- Process plant.
- Marine systems.
- Riser system.
- Anchoring and mooring.

Full details concerning the range of class notations can be obtained from LR's Rules for Floating Production Installations although the following is a typical FPSO class notation:

✠ OI 100 AT Floating oil production and storage installation, PPF.

✠ OMC, IGS, SBT (LR), COW (LR).

3 Integration with the Project

3.1 Project Team Manager

On recent projects, LR has offered an effective way to deal with classification through greater integration in the project team. Figure 2 shows a typical project team set-up. A dedicated project manager will be placed in the project office to co-ordinate all aspects of the classification process. His first task is to establish the most cost efficient means of interface between LR and the project. He will prepare a project specific quality plan, procedures and work instructions controlling the classification activities which interface with the client's quality system. He will identify the requirements for design appraisal and survey activities and agree the extent of work to be performed for each task.

The project manager will also be available to take an active part in face-to-face discussions on any problems raised. Thus the lines of communication in the design phase are straightened considerably. He can also assist with equipment procurement by instructing vendors on their classification responsibilities and issue formal work instructions to the appropriate LR office(s) when purchase orders are placed.

This integrated approach minimises the clients' own efforts and significantly reduces the amount of communications and documentation required for the classification process. Having the work monitored on a continuous basis, both technically and with regard to cost control and schedules, can achieve worthwhile cost savings.

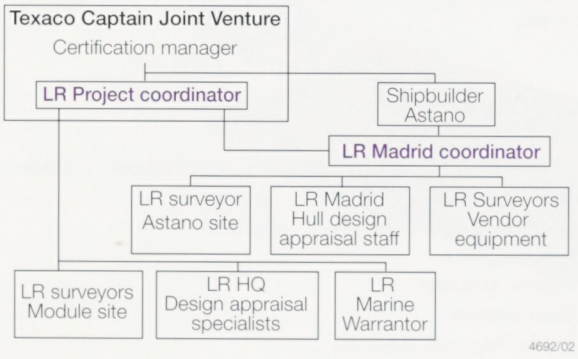


Figure 2

3.2 Project Systems

Inherent in this strategy are a number of other key improvements which LR has made to enhance their service. These include:

- Document image facilities utilising a cimage document management system (Cimage). This facility offers a major potential time and cost saving for the operator with regard to the handling and submission of documents and has improved drawing approval turnaround time. It is possible to build links between the designers CAD system and Cimage. The approved plans can be returned to the client using the same medium as the original submissions.
- An independent project management system (IPMS) for the control of project correspondence and documents. IPMS can be provided in standalone or network versions and can thus be mounted on a laptop for full portability if necessary. The LR project manager will use this system to monitor document turnaround requirements and generate comment response sheets (CRSs) which record document approvals.
- A stand-alone system (Microsoft Access) for monitoring and control of survey work and survey costs.

Successful project integration will also develop a close interaction with the client at an early stage of the design. All the above systems can be used in conjunction with the project team to provide design appraisal within the client offices where needed.

Early agreement on fundamental design issues such as site environment, design cases, fatigue data, mooring system etc. can help to resolve and avoid problems which could be encountered in the design and construction of the installation, and which, if left uncorrected, could lead to expensive modifications and repairs. Concept design evaluation as outlined in the following Section provides a route to identifying problem areas early in the design phase.

4 Concept Design Evaluation

The concept design evaluation study is intended to establish the integrity of the design and as such should be applicable to manned floating production installations, provide the safety goals of the intended design and satisfy the field's regulatory regime.

Offshore legislation world-wide poses new challenges for offshore operators as they seek to achieve and demonstrate the safety of their installations, both to safeguard their work force and also to guarantee the continued operations of their assets.

In line with these challenges LR has developed the Concept Design Evaluation Service (CDE).

The objectives of the programme are:

- to ensure that the design is based on satisfactory standards and could be developed for classification/verification.
- to verify that the floating production concept chosen for the field development will result in an acceptable installation and that no major changes and resulting cost penalties will be necessary because of safety or legislative requirements.
- to ensure that the potential loss of human life, environmental pollution, and property and business interruption losses, as a consequence of an accident are "As Low As Reasonably Practicable" (ALARP).

CDE will assist the operator at an early stage to consider the legislative requirements and identify areas of concerns which could affect the design (see Figure 3). For this purpose the CDE incorporates two examination phases, the concept design appraisal and the concept safety evaluation.

4.1 Concept Design Appraisal (CDA)

The CDA is specifically tailored to match the overall objectives of the design development and will normally cover the fundamental design aspects. The CDA is based on review and appraisal of the design documents covering the most important areas of the FPSO development, namely:

- general layout arrangement
- main hull structure and storage
- mooring system/turret
- stability
- process/utility systems
- environmental criteria

The intention of the review is to ensure that the design is based on satisfactory standards, to highlight at an early stage any areas requiring improvement and to verify that the design can be developed to meet all applicable legislation.

A typical assessment carried out as part of the CDA could include preliminary mooring analysis, initial stability conformance etc.

4.2 Concept Safety Evaluation (CSE)

The CSE assists the operator to define acceptable offshore criteria which will form the basis of the design safety assessment and provide a clear design audit trail to justify continuation to the detail phase.

Safety is a line responsibility and the operator has to set out a strategy approach to safety requirements which cater for the technical integrity of the development for the project life cycle. The scope of such an approach is to set the goals to safeguard human life, the environment and the invested capital. It also addresses the preparation and submission of the documentation which would support these. In order to successfully achieve a sound basis for the safety design, CSE includes the following:

- project design and operational philosophy decision support
- review of proposed design and operational requirements
- hazard identification
- fire and explosion risk analysis
- review of mitigation measures
- assessment of Escape, Evacuation and Rescue effectiveness

The aim of the fire risk analysis is to get an appreciation of the probable hydrocarbon releases and their impact on the design layout, the temporary refuge and the escape and evacuation provisions.

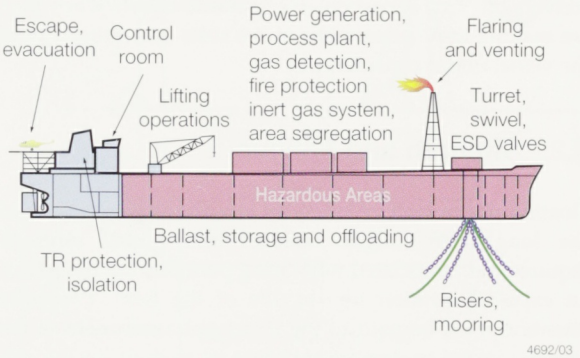


Figure 3

5 Conversions

5.1 Conversion Considerations

The decision to convert an existing vessel will be heavily influenced by the cost and completion time of a conversion against that for a new building. The use of converted tonnage can offer a faster and lower cost route to production with the associated cost savings permitting economic advantages to the development of the field.

The decision will, however, also be influenced by other considerations such as:

- availability of suitable tonnage
- new building market situation
- harsh environment and long field life
- national regulations to be applied
- fast track project

The condition of a tanker being considered for conversion can only be determined by carrying out an extensive inspection. It is essential that this is done by surveyors who have the required level of expertise to correctly assess the condition of the vessel and its suitability for a floating production role. LR can provide this service to clients and has assessed in excess of thirty different tankers, some of which were found to be unsuitable for conversion. The service utilises a specialist surveyor who normally becomes part of the client's own team for the duration of the inspection. He will report his findings, making recommendations concerning the suitability of the tanker and the extent of renewals likely to be required for the conversion. This is particularly useful to clients when they are making their assessment of the costs and suitability of the vessel under consideration.

5.2 Strength and Fatigue

Floating production installations must be able to withstand the long term fatigue stresses and global strength requirements associated with being permanently moored at an exposed location for the life of the field. Particular attention must be paid to the structural assessment of the selected vessel to demonstrate that its as-built design will be suitable for the new operations. Because of this, and in addition to the planned modifications proposed for conversion, there will be a level of enhancement and repairs to be carried out. The following points outline some typical issues for consideration:

- Hull girder strength and fatigue life will be required to be assessed for the FPSO role. The acceptability of the hull will depend on the actual section modulus and the existing detail design being suitable for the new site loading conditions.
- Steelwork is to be suitably protected against corrosion by means of coatings, a system of cathodic protection or other acceptable method. Requirements must be evaluated taking account of relevant factors such as field life, tank contents and service inspection. Severe problems could occur in ballast tanks and slop tanks.
- Provision of a power generation system, for either produced gas or fuel oil, to cater for the high power requirements associated with offshore processing operations.
- Upgrading of marine systems to cater for hydrocarbon processing, storage, loading and offloading operations and ship integrity in the form of gas inerting, ballasting and position maintenance.
- Additional active and passive fire protection systems to provide coverage for process plant, enhanced accommodation, temporary refuge, escape and evacuation facilities.

Converting an existing vessel into an FPSO is never a simple matter as it involves many uncertainties. Provided that the tanker chosen after survey is in good condition and that a satisfactory level of safety has been implemented during its conversion to an FPSO, many of these uncertainties can be efficiently managed.

A good example of this is Bluewater's "Uisge Gorm", pictured under conversion in Cadiz in Figure 4 and now successfully operating in the Amerada Hess Fife Field. The anchor spider is shown in the picture insert. This conversion was completed on time and it is estimated that first oil was produced approximately one year quicker than a comparable new build FPSO would have achieved.

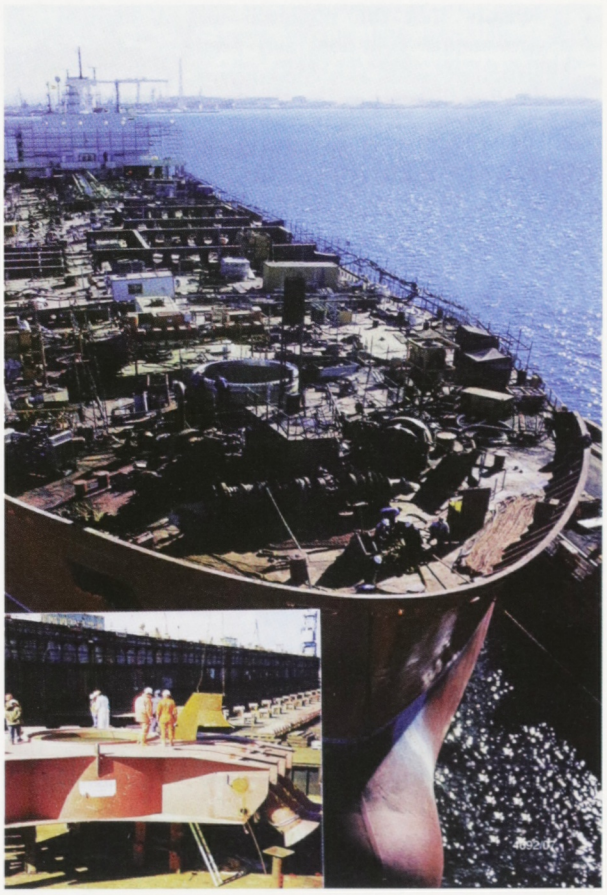


Figure 4

6 FPSO Structures

6.1 Strength and Stability

Floating production installations will be designed to endure long term deployment, perhaps in an extremely harsh environment. In order to minimise production down time, vessels may be expected to operate without scheduled drydockings and be surveyed on station.

In order to fulfil these operational requirements it is necessary that the structure has adequate overall strength consistent with the long term site environment, and good local detail design to ensure satisfactory fatigue performance. In addition, high quality construction standards will be required of the building or conversion shipyards.

Ship classification rules can be used as an appropriate standard for the minimum structural requirements of an FPSO, however, additional factors will have to be considered at an early stage.

The maximum extreme wave bending moment and shear force is to be determined for the design environment, generally the fifty year storm. This will evaluate the long term extreme responses and will be based on the specific wave spectrum for the proposed location. The maximum wave bending moment and shear force may exceed the rule values, particularly in exposed locations.

In calculating the still water bending moments and shear forces, a range of conditions should be considered. These will include full load, ballast and intermediate conditions. In addition it will be necessary to include conditions where each tank is empty in turn. This will then allow the in-situ inspection of tanks to be carried out with minimum disturbance to production. Some recent designs have considered conditions with adjacent tanks empty to allow the possibility of "hot work" in tanks, should in-situ repairs ever be necessary.

It is unlikely that the additional weights of process equipment etc. added to a converted ship will significantly increase the still water bending moment, however, stability aspects will require careful examination when assessing the feasibility of a conversion. This is both because of the likely increase in the centre of gravity and the necessity to meet the requirements of damage stability criteria such as those specified in MARPOL.

6.2 Fatigue

It is essential that the fatigue performance of the vessel is carefully assessed. Although the design of trading tankers has a good degree of structural redundancy and can sustain fatigue cracking without catastrophic failure, they have the advantage of a regular dry-docking schedule which allow any necessary repairs to be carried out. As indicated earlier, an FPSO unit will generally be expected to operate continuously throughout the field life without any scheduled drydockings.

FPSOs may experience a more onerous fatigue environment than a trading tanker because they are permanently exposed to fatigue loading, whereas a trading tanker may only spend approximately 70% of its life at sea. FPSOs also experience a highly directional fatigue load spectrum from a narrow band from ahead. For conversions, the fatigue analysis should account for previous service. Reducing the risk of fatigue damage can be achieved by good detail design, for example, by following the requirements specified in the ShipRight FDA procedure. Critical areas include the side shell longitudinals, particularly those between the deep draught waterline and a couple of metres below the light draught water line. The use of symmetrical sections is preferred for these longitudinals although this is not mandatory. It may also be necessary to increase scantlings above the rule minima in these areas.

For tanker conversions it is generally necessary to improve local detail design by the addition of lugs at bottom longitudinal to transverse connections, and the addition of soft brackets and backing brackets on side shell longitudinal to transverse connections, if these are not already fitted. (See Figure 5).

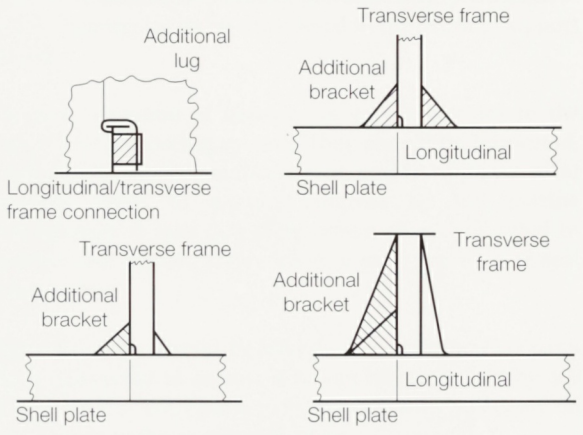


Figure 5

6.3 Additional Requirements

The following special studies should be carried out in addition to classification rule requirements:

- For new build vessels a finite element (FE) analysis of a representative portion of the vessel's hull. Loading scenarios in line with the ShipRight SDA procedure should be considered.
- Structural analyses for the integration of the mooring system.

- Structural assessment for the deck structure locally in way of process equipment supports. The design of skid structures should take account of loadings due to bending of the hull, and vessel hull/skid structure interaction.
- Sloshing analysis. Generally new build FPSO units have been designed with relatively short cargo oil tanks (~25m) which have not been found to have high sloshing pressures. However, problems may be encountered in tankers for conversion with long tanks fitted with swash bulkheads. Partial plating-in of the swash bulkhead may be required.
- The likelihood of slamming and shipping green seas on deck should be investigated, normally by a combination of model tests and analytical methods. Where necessary, appropriate action should be taken. This may include additional strengthening or draught/trim limitations.
- Structural appraisal will also be carried out for the accommodation block, helideck and the flare tower.
- The structural interfaces between different design contractors' areas of responsibility requires special consideration. Modern projects involve many different engineering contractors each dealing with specific items of structure in isolation and the classification society may be the only body looking at the interfaces in the global context. Examples include crane pedestal to hull connections, process equipment supports, hull connections and mooring system integration.

7 Turret Mooring Systems

This section of the Paper concentrates on internal turret mooring systems as they are now the most popular arrangement for FPSO mooring. The mooring system chain table is attached directly to a cylindrical turret, which is supported by a bearing system. The bearing is mounted internally within the FPSO, and this arrangement allows the FPSO to weather vane around the mooring, thus minimising mooring forces. (See Figure 6).

An internal turret positioned near to the bow, gives the FPSO good weather vaning capabilities. If the turret is positioned nearer to amidships, some thruster capacity will be required to maintain the FPSO heading into the weather, to minimise mooring forces.

Two types of import arrangements, stack swivel or drag chain, are used to allow input risers, output risers and control signals, to be passed from the fixed mooring to the rotating FPSO. The diameter of the turret is influenced by the import arrangements and the number and size of risers.

Some important aspects associated with the design of the turret mooring system are discussed in the following sub-sections.

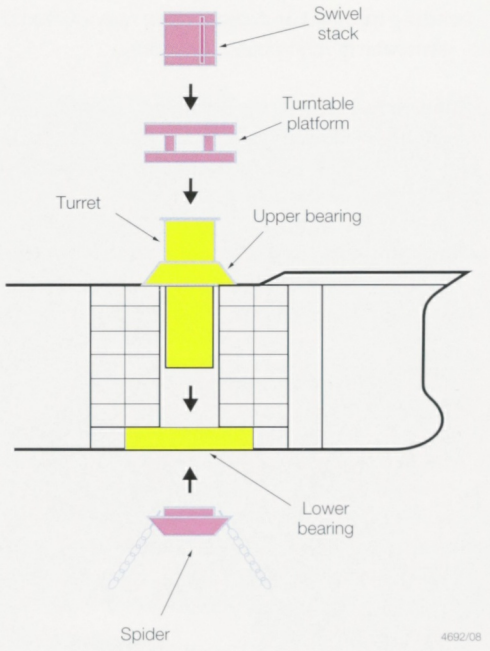


Figure 6

7.1 Turret Design

The mooring turret and its integration into the hull are key components of an FPSO installation and require thorough assessment. A site specific structural analysis is required to address the following:

- Site specific criteria should be used for mooring loads, and global bending moments and shear forces at the turrent position.
- Load combinations arising from:
  - turret mooring loads,
  - overall hull bending moments and shear forces,
  - internal and external pressure loads, covering the intended range of drafts and loading conditions, including non-symmetric cases as applicable.
- Guidance on FE model mesh size is given in LR ShipRight.
- The effect of stiffeners are to be included in the model.
- Boundary conditions.
- Possible load enhancement due to "Green Seas".
- Possible load enhancement due to Slamming.
- Sloshing.
- Overall strength, buckling strength and fatigue.
- The strength of the turret casing and the primary transverse and longitudinal supports should be evaluated. Reference should be made to the LR ShipRight SDA Manual, for guidance on the load cases to be considered and the permissible stress levels.
- NDE philosophy.
- Welding.

Continuity of primary longitudinal structural elements is to be maintained as far as practicable in way of the turret opening. Reduction in hull section modulus should be kept to a minimum and compensation is to be fitted where necessary.

Turret structures are made up of an arrangement of stiffened plates with bulkheads and ring frames as appropriate. Castings may be used to reduce the amount of welding in complicated detail joints.

To permit in-service inspection of all areas of the turret and support structure, suitable means of access by an arrangement of platforms, stairs and ladders should be provided.

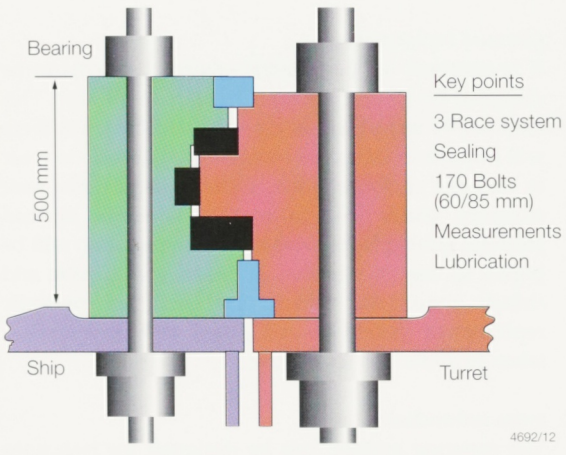


Figure 7

7.2 Bearing Design

For small or medium sized turrets, the slewing bearing is usually a large diameter roller bearing, with vertical, transverse and moment loadings being transmitted within the sealed bearing (see Figure 7). Alternatively, and for larger diameter turrets, the turret may be supported by an arrangement of bogie bearings running on a circular track. These transmit vertical and moment loadings only, with a separate system used to prevent uplift. Transverse loadings are transmitted by a series of radial bearings running on a circumferential track around the turret.

Bearing design loads and life spectra are determined from mooring line loads, which have been derived from model testing of the FPSO and mooring system. Bearing design should be based on the minimum of either the field life or 20 years, and should satisfy the requirements of recognised codes such as:

- SO 281 : 1990(E) – Method of calculating dynamic load ratings and rating life of roller bearings.
- ISO 76 : 1987 – Roller bearings, static load ratings.
- ASME 77-DE-39 – Design criteria to prevent core crushing failure in large diameter, case hardened, ball and roller bearings.

To ensure the efficient operation of any bearing, the correct support stiffness and flatness tolerance, applicable to that type of bearing, must be considered in the bearing support design.

The free operation of bearings is very important to the integrity of a mooring system. They should be lubricated, preferably by an automatic system, and have a system of multiple seals to prevent ingress of the marine environment. A leak detection system should be fitted to monitor seal performance and give early warning of seal deterioration.

Roller bearings should be designed so that internal parts can be inspected in service. This can be carried out by use of ultrasonic or eddy current techniques, with a comparison being made to the as-new condition.

External parts of bearings, and their attachment arrangements to the supporting structure, should be accessible for inspection purposes.

7.3 Swivel Stack Design

The function of the swivel is to transfer hydrocarbons and utilities from/to the flexible risers, which are routed through the turret, to rigid piping at the manifold deck level. The swivel arrangement allows the FPSO to weather vane around the geo-stationary turret cylinder via a bearing system taking up a heading of least resistance depending on the combined action of wind, waves and current (see Figure 8).

The stack is comprised of a number of separate swivels which are used for the production of oil and gas and the hydraulics, chemicals and utilities for the well. The swivels

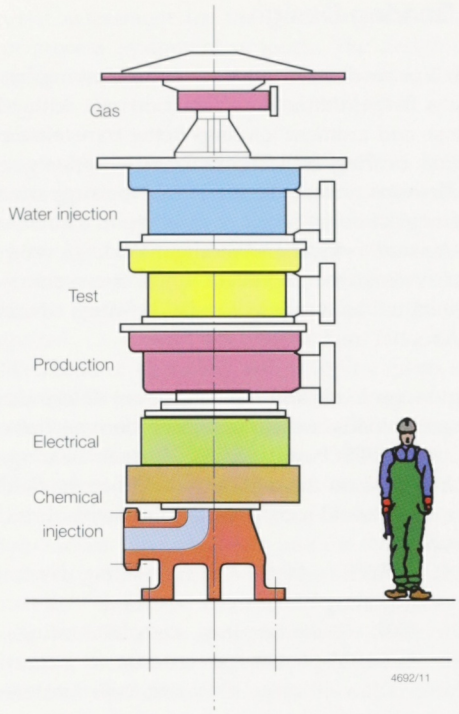


Figure 8

are joined together into a vertical column on the centre line of the mooring turret, by either a bolted flange or clamped arrangement. Each swivel is split into an inner and outer part, joined by a bearing to allow free rotation along its vertical axis. One half of each swivel is attached to the mooring turret, and the other half to the FPSO structure. The rotating part of the system consists of the tanker and gantry structure. The FPSO gantry structure supports the fixed swivel stack within the manifold structure to enable hydrocarbons or utilities to transfer between the two parts.

Swivels include an arrangement of seals to contain the contents. The seal materials have to be compatible with the swivel internal and external environment, pressure and deflection criteria, in order to achieve adequate seal life. Due to high operating pressure and temperature of some swivels, multi-path sealing arrangements are also used.

Typical concerns associated with the swivel stack structure are:

- allowance for FPSO motion
- evaluation of swivel stack support loads
- swivel pressure containment requirements

To allow servicing and change out of swivel stack items, mechanical handling facilities need to be arranged above the swivel stack with laydown and workshop areas alongside.

7.4 Anchor Lines

Lloyd's Register's classification requirement for minimum factors of safety on anchor lines is as follows:

– Intact	1.85
– Damage equilibrium	1.35
– Transient (Short term cycle of motion following sudden line failure)	1.10

The acceptance of these factors of safety is conditional on the following:

- dynamic analysis
- acceptable arrangements for in-service inspection
- arrangements for immediate shutdown of production or transfer of product in the event of sudden line failure
- fatigue life requirement to be satisfied for main mooring components.

Note that only one set of factors of safety is given, representing the extreme storm case. Factors of safety are not given for "operating" cases. FPSOs using flexible risers will have a high operating threshold and it is more important to ensure long-term integrity of the mooring system by means of fatigue life assessment and corrosion and wear allowances etc., than to arbitrarily apply high factors for operating modes.

7.5 Mooring Inspectability

Mooring systems for FPSOs are generally difficult to inspect in-situ. The opportunities available for regular close inspection at Mobile Offshore Drilling Unit (MODU) rig moves do not exist for floating production installations and the often complex anchoring arrangements – mixed materials, triple chain section, buoys, anchor piles etc. –preclude the option of routine raising of the system for close inspection.

Designers on the whole do not pay sufficient attention to inspectability. Inspection strategy and potential inspection problems have to be considered as design issues, and as such considered at an early stage as part of an integrated design process.

There are a number of issues linked to the basic one of inspectability which should be considered in design:

(a) planned replacement.
It is common for permanent mooring systems to be designed for 10 years or even 15 years service life. This may not be unrealistic as a general objective but there will be parts of the system specially vulnerable to wear or damage or degradation, such as, chain links near stoppers, chain links in way of fairleads, fairlead sheaves, joining links, wire ropes (degradation will be higher in way of winches, fairleads, splash zone and thrash zone), for which the need for periodic replacement should be recognised and design steps taken to allow this to be done.

(b) extra redundancy.
The mooring system, can be designed for two lines removed – one removed for planned inspection or replacement and one for failure while in this depleted condition. As this is a planned situation, reduced, seasonal design environmental criteria can be applied.

(c) enhanced non destructive examination (NDE).
Parts of the mooring system which will not be inspectable, eg. chain cable leading to a buried pile lug, should be subject to enhanced non-destructive examination at the manufacturing stage.

Bearing in mind the consequences of lost production caused by the replacement of anchor lines, some conservatism in design is worthwhile especially in the case of long field life.

8 Process Plant

8.1 General

The processing of oil and gas constitutes the economic reason for FPSO field utilisation.

The process plant is usually placed on a frame structure elevated at a height of about 3.5 metres above the main deck. Equipment modules most sensitive to motions are likely to be placed towards midships. The modules are assembled in such a way to allow easy implementation and also fulfill the production requirements of the field. Figure 9 shows the Texaco Captain FPSO with process modules being assembled during construction.

The major factors currently affecting the type and function of the process plant on a floating production facility are:

- the processing equipment capable of operating efficiently under ship motion conditions.
- the improvements in mooring and riser technology allowing process operations under more extreme conditions.
- the renewed interest in production of liquefied gases and methanol which require a more complex process plant.
- the emphasis on the use of conventional equipment which is readily available.



Figure 9

8.2 Crude Oil Separation

Efficient crude oil separation is one of the key elements of any production facility. This should be considered particularly for a floating production facility where the vessel motions affect the various processing liquid phases and conflict with the separation process. From these motions, roll and pitch are the primary parameters for process and instrumentation design because of the induced frequencies and the risk of resonance for the gas/oil and oil/water interfaces. Sway, surge and heave are of secondary importance regarding process design but of greater importance for the design of turbines, motors etc.

In addition, sloshing accelerations in liquid process units can be as high as 0.5 - 0.7g and must be considered in the design of their structural supports.

A typical separation and oil processing system on an FPSO comprises two primary separators, a second stage separator, crude oil heaters, transfer pumps and an electrostatic coalescer (see Figure 10). Separators are usually designed to operate in pitch and roll motions of up to 9 degrees. Each separator splits the incoming fluid into three phases: water-in-oil mix, water and gas. Heating of the crude to enhance separation takes place between the primary and second stage separator. Crude oil is finally dehydrated to the desired export specification by pumping through an electrostatic coalescer. Dry oil from the coalescer is firstly cooled by passing through a heat exchanger and then stored in the tanks.

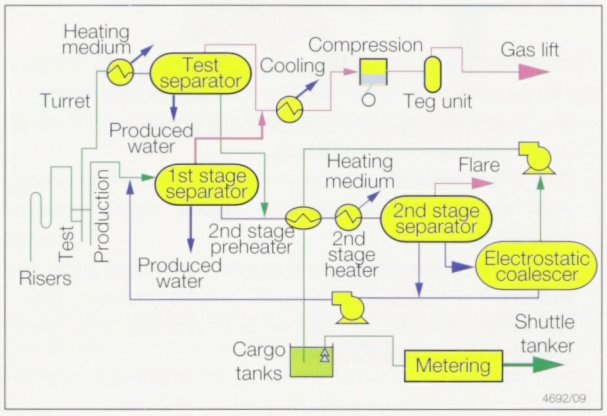


Figure 10

8.3 Gas Production

Produced gas is normally compressed in stages (Low Pressure – High Pressure trains) to attain the pressure required for either reinjection or export depending on the field requirements. Part of the gas provides fuel for the main power generation. FPSOs usually use a number of gas turbines with diesel standby and additional emergency capacity.

Gas flaring on floating production presents a number of unique constraints such as thermal radiation and noise and deck loadings induced by vessel motions and weight. Because of sea motions, the flare tower will impose considerable moments and forces on the ship structure which have to be accounted for, particularly in the case of tanker conversions.

8.4 Hydrocarbon Processing Utilities

Hydrocarbon processing also requires a number of utilities which include the drains system, diesel fuel storage and distribution, sea water systems, compressed air supply and chemical injection facilities. Specific utilities termed 'marine systems' typically refer to the systems associated with FPSO operations such as:

- Storage/Offloading System – combines submerged pumps installed in the tanks connected to an export ring main permitting product transfer from any combination of tanks to the shuttle tanker.
- Ballast System – comprising segregated ballast tanks and pumps to ensure that the FPSO can be maintained on an even keel or slight trim during loading conditions on the field and during sea tows.
- Inert Gas System – uses dedicated gas generators with the function of maintaining the atmosphere of all oil storage and slop tanks in a non flammable condition at all times as a protection against a tank fire and explosion.
- Thruster System – provides active heading control which reduces fishtailing effects and enables the vessel to offset heading in order to maintain the bow at optimal position with respect to wave forces.

8.5 Additional Areas for Investigation

In addition to compliance with normal rule requirements during the detail design and building stages, the following key areas can benefit from LR's input and active consideration at an early stage in the design development:

- process plant safety evaluation and layout optimisation.
- separation of the hazardous and non-hazardous areas.
- integration and control of the process plant, ship engineering services and wellhead systems.
- design appraisal of the flexible risers and suitable end fittings.
- integration of power supplies for various modes of ship operation and emergency conditions.
- design appraisal of marine systems, emergency systems and position maintenance for the required storm conditions.
- consideration of topside materials, protective coatings and corrosion treatments.
- consideration of marine survey examination period and the means to carry out inspections.
- flaring operations and environmental effluents.

9 Flexible Riser System

9.1 Design and Construction

The properties which make flexible risers attractive for FPSO applications is their ability to conform to relatively large displacements and comparative ease of installation. These attributes are accompanied by the ability to contain large working pressures, together with high tensile strength and, in deep water application, being able to resist external hydrostatic pressures. To achieve this, risers are constructed from multiple layers of spirally wound steel fibres, with intermediate layers of continuous plastic. The development of these complex structures in a practical form for long term use under arduous environmental conditions, represents a considerable triumph for design and production engineering.

A particularly demanding element in this development has been the design of suitable end fittings, which are required to provide continuity of strength and pressure tightness at tie-in points. This is achieved by anchoring the tensile armours in a shaped cavity with epoxy resin and by capturing the inner liner by a sealing ring to maintain pressure tightness at the joint. (See Figure 11). End fittings are also designed to resist full burst pressure and failure tensions with adequate margins.

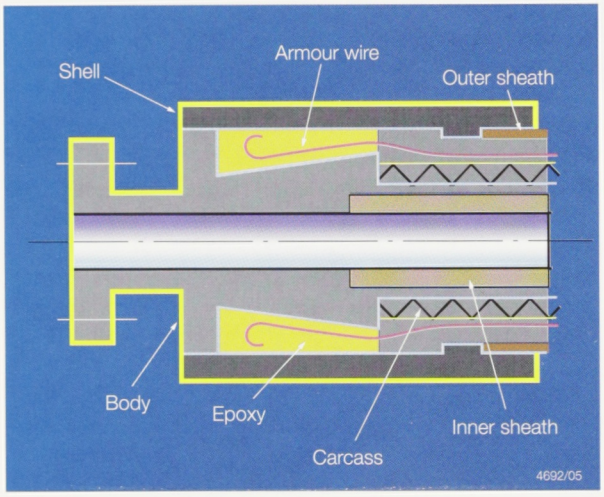


Figure 11

9.2 Analysis

A number of routines are available commercially for the analysis of global response of risers for both static and dynamic loadings including large displacements, the stress analysis of the internal layers of the pipe section has received considerably less attention. The complex internal structure of flexible pipe, together with the difficulty of inspection after fabrication, makes the accurate analysis of internal stresses a vital requirement. Thus LR has developed an independent routine for this purpose. The LR program COMP-WALL calculates stressed and displacements arising from given combinations of internal and external pressure, axial forces, layer temperatures for bonded and unbonded multi-layer pipes, subject to prespecified boundary conditions. The program allows the yielding of individual layers in order to calculate load factors for first yield and ultimate strength.

Figure 12 shows a typical FPSO subsea development using a "lazy S" flexible riser system. Such an arrangement would include buoyancy tanks, end-fittings and bend stiffeners at the turret entry, which allow an acceptable graduation of curvature towards the rigid boundary. Critical areas requiring detailed assessment include abrasion and wear of the outermost layer at the touch down point in the seabed, the large curvatures expected at the buoyancy arch, at the attachment to the vessel and crushing of the riser section in the clamping system at the arch location.

Although manufacturing and installation process are monitored at all critical stages, the individual elements of the completed pipe are inaccessible for direct inspection. Localised or progressive loss of structural integrity is difficult to detect before a serious failure occurs. Thus, a rigorous adherence to quality control procedures, together with a detailed independent check on design loads and pipe strength is required for design appraisal and certification.

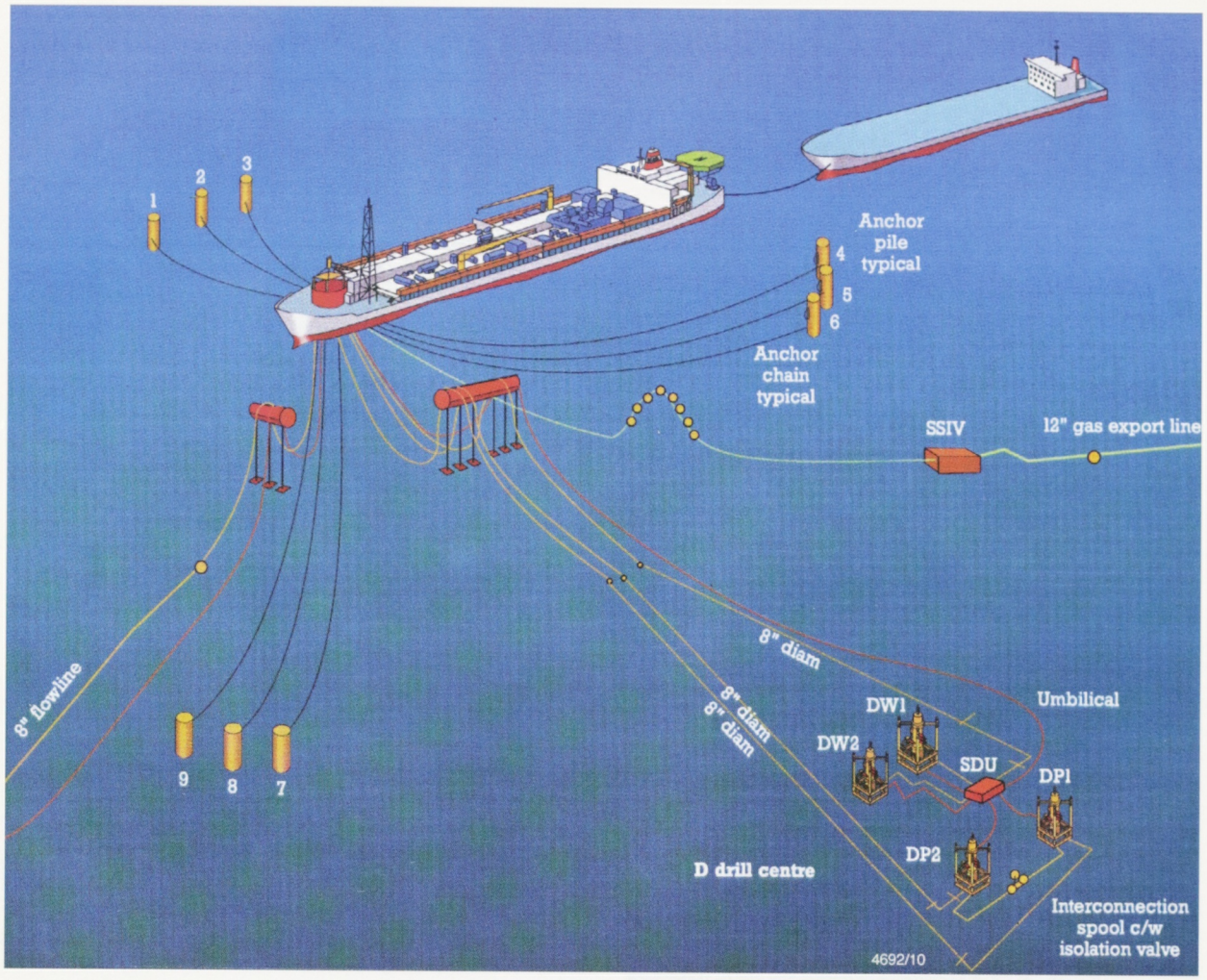


Figure 12
Typical FPSO subsea development

10 Inspection and Repairs

10.1 Survey Inspections

To ensure that the installation remains in a satisfactory condition it is a requirement for classification that periodic surveys are carried out during service. These in-service inspections provide a detection and monitoring capability relating to the safety of the installation including structural damage and fatigue cracking and take the form of annual and major surveys.

To facilitate internal surveys it is essential that each compartment is properly cleaned and gas freed and that appropriate means of access and lighting are provided. This is clearly of particular importance for the in-situ survey of FPSO installations. The provision of access arrangements which enable the required surveys to be completed effectively and safely should be considered during the design stage.

The Rules provide for In-Water Surveys (IWS) to allow inspections to be carried out on location in lieu of dry-docking to obtain the same information normally obtained from dry-docking. In this way the vessel can remain on station provided that the vessel's condition remains satisfactory. It is not necessary to remove hull coatings unless anomalies have been discovered and further detailed examination required.

Continuous survey of the hull and/or machinery, whereby all surveyable items are inspected in rotation over a 5 year period, is acceptable provided a detailed programme is developed.

A schedule for survey should be produced to guide and control the inspection and replacement philosophy. The schedule should address:

- The overall design configuration
- Field life potential
- Minimum regulatory requirements
- Personnel qualification
- Inspection schedules for all appropriate components/systems
- Replacement schedules
- Methods and procedures
- Extent, frequency and circumstances for application of NDE
- Reporting and remedial actions

Particular attention is to be paid to critical areas, areas of suspected damage or deterioration and to repaired areas. The survey should take into account locations highlighted by operational experience and design assessments.

A strategy receiving considerable attention is the probabilistic approach to inspection. Schedules developed for fixed jacket structures and mobile offshore units have demonstrated potential for significant cost savings without compromising safety criteria. This reliability approach to survey will be particularly suited to FPSO's which are intended to remain permanently on station during the whole of their field life.

10.2 Structural Repair

Whilst the necessity for repair may be effectively minimised by careful attention to detail design, fabrication and analytical calculations, experience indicates that structural problems can occur in service. Not all defects will have developed as a result of fatigue however, and many will be due to inbuilt fabrication and welding defects. Following discovery of a significant defect, a detailed examination should be carried out in order to fully assess the structural implications. The following information should be obtained as appropriate:

- the location including structural boundaries when involved
- whether the defect is internal/external
- the extent of the defect
- the risk of contamination
- the prevailing conditions.

Based on the information available, a decision may be agreed by the operator and certifying authority regarding appropriate action. This may take the form of inspection monitoring and review, weld grinding or complete structural repair depending on the nature and severity of the problem. The intention is to ensure that the structural integrity of the unit is not compromised and remains fit for purpose. When developing proposed remedial repair and monitoring procedures consideration should be paid to the location and criticality of defect, facilities required, access arrangements, materials/repair method/weld procedure, protective coatings, post repair inspection and subsequent monitoring program.

Typical repairs would range from carefully controlled grinding for small surface cracks to welded repairs of extensive damage and possibly local structural modification where repeated repairs have been made.

The in-situ structural repair of FPSOs offers a particular challenge. To minimise any impact on production it may be necessary to abandon pre-conceived ideas and consider more innovative measures.

11 Conclusions

The floating production system has been a field development option for some time. In recent years the drive towards cost reduction coupled with advances in technology and also a floating system's suitability in deep water has led to an increased use of the FPSO world-wide. Data from Offshore Data Services' Offshore Field Development International database shows that some 37 units are scheduled for installation in 1996, followed by 21 in 1997.

Floating production offers a safe and cost effective alternative to fixed platform technology with the added benefit of easy abandonment. However FPSOs are production systems which require the integration of a number of major components such as hull, mooring system, process plant, subsea system etc. in order to offer a faster route to production with the associated cost savings for the operators. This may well involve construction activities in several world locations with different companies.

Alliance style contracts further emphasise the need for support being provided early in the project in order to ensure integrity and minimise costly modifications. LR is contributing knowledge and expertise to many current FPSO projects and by working within the project team, has demonstrated a more flexible and efficient approach.

With it's international set-up, LR's objective is to provide a total service based on standards which are in line with the industry's need for "fitness for purpose". We believe this can be best achieved by maintaining closer co-operation and adapting positively to the needs of our customers.

12 Acknowledgements

I wish to thank my colleagues for their assistance in writing this paper, in particular Mr Thanos Koliopulos.

LR *Technical Association*

Practical aspects of inclining experiments

by F. Morishita

Lloyd's Register

Paper No **2**
Session 1996–1997

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LR *Technical Association*

Discussion on the Paper

Practical aspects of inclining experiments

by F. Morishita

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Practical aspects of inclining experiments

by F. Morishita

DISCUSSION

From: Mr. C. M. Magill

I would like to congratulate Morishita San for a well written Paper and also for his presentation tonight in a language which is not his mother tongue.

For some time I have been aware of Mr. Morishita's intent to share with colleagues the statistical data on the lightweight parameters of ships built in Japan, which he has been collecting for a number of years. Whilst such data can be excellent reference material, it can be even less exciting than watching paint dry! However, I am pleased that he took up one of my suggestions and wrote a Paper for the LRTA on inclining experiments, for which much of his data is very relevant.

As he has observed, an inclining experiment is the only accurate method of determining the position of a ship's centre of gravity and, since this is intimately related to the stability characteristics of a ship, is of vital importance for the whole of its working life. Increasing international legislation with respect to the stability of ships, in particular the damage stability criteria, now provide designers and builders with very small margins for achieving compliance and the accuracy of the conduct of an inclining experiment is even more important today than it was when only intact stability matters were addressed. I believe Mr. Whittaker is likely to comment further on this; I will therefore confine my own comments to the lightweight data presented in Appendix B.

The lightweight data presented by ship type will be a useful reference point both for plan approval Surveyors and local Surveyors when assessing initial loading information submitted to them. However, it is the data concerning the VCG (Figure 23) which will be of most value at the time of the inclining experiment, and perhaps, this could be expanded to a number of plots by ship type to provide quicker and easier reference.

Finally, your plot of lightweight against year of midship section (Figure 24) is most interesting. Can Mr. Morishita say whether significant Rule changes are affecting the downward trend and, if so, should this be indicated as a series of steps or does he think that the trend is representative of an increasing use of direct calculation methods during the period shown?

To: Mr. C. M. Magill

Mr. Magill's suggestion to write an LRTA Paper on this subject was very helpful, and provided an outlet for my gathered lightweight data.

As mentioned by Mr. Magill, the damage stability criteria, in accordance with Part B-1, Chapter II-1 of SOLAS 1974, as amended, provides designers and builders with very small margins for achieving compliance. In particular, stability margins for container ships, PCCs and RO/RO cargo ships are very tight. This situation does require the accurate estimation of lightweight particulars at the design stage and precision when conducting the inclining experiment.

Mr. Magill's comment regarding the value of additional plots of VCG data against ship type is recognised; reference is made to Figures 23.1 – 23.9.

With regard to the last paragraph of Mr. Magill's question, it is considered that the downward trend of lightweight/LBD from 1977-1990, for Panamax bulk carriers, was, as Mr. Magill stated, due partly to an increasing use of the direct calculation methods for scantlings, but also to the optimisation of structures for double bottom and deep tank bulkheads. The use of higher tensile steel was another major contributor.

However, two ships built in Japan between 1996-1997 suggests that, following a change in the Rules, an upward trend from 1990 may result. Reference is made to Figure 24.1.

From: Mr. D. V. Whittaker

Mr. Morishita should be congratulated for endeavouring to clarify the requirements for inclining experiments by combining the contents of Annexes 4 and 5 of Part D, Section 15 of the MDSPM which give details of the IACS recommendation and the IMO requirements which are incorporated into the Code on Intact Stability, IMO Res. A.749 (18).

After listening to this presentation my immediate thoughts were that the basic requirements are the same as they were when I studied at college. However, there have been changes which affect the determination of the lightweight and its VCG/LCG by the inclining experiment, both directly and indirectly. The first is the use of water ballast

transfer as the means of providing the heeling moment. When using this method special care needs to be taken to ensure that the correct weight of water ballast has been taken into account and its vertical and longitudinal position of the centre of gravity correctly established. This is particularly important as the shift of water ballast may introduce a vertical shift in the ship's VCG, which may not be encountered with a solid weight transfer. The LRTA Paper identifies how these aspects should be dealt with.

Traditionally, the lightweight particulars have been determined to check whether the design values used in the preliminary intact stability calculations are valid, and that the as-built ship will meet the statutory requirements. As the intact stability GM values were often quite large, there was scope for some discrepancies in lightweight particulars. Providing the minimum statutory requirements were still met, greater tolerance could be exercised in accepting the inclining experiment results. This position has changed somewhat with the introduction of damage stability requirements for a greater variety of ships, and in these cases the margin for error can be greatly reduced. For compliance with damage stability requirements, the maximum permissible VCG is normally lower than that required for intact stability. Consequently, the margin between the actual and permissible VCG can be, and often is, very small or even on the limit. In order to ensure that the ship meets the requirements, it is important that the lightweight and its VCG are determined as accurately as possible. It is therefore of some concern that within LR we are witnessing a lessening of the standards being applied by those organisations undertaking inclining experiments, which consequently places a greater responsibility on the Surveyor attending the inclining experiment. Some of the areas of concern have recently been advised to Regional Managers, these include:-

(i) Non-attendance of an LR Surveyor at an inclining test,
(ii) Inability to record draught marks due to bad weather, but allowing the inclining test to continue,
(iii) Replacing all the pendulums with other measuring devices,
(iv) Failure to plot the heeling moment against the tangent of the heel angle (this should be done during the test to ensure that acceptable data is being obtained),
(v) Failure to follow procedures for weight shifts, resulting in incomplete test results,
(vi) Failure to submit a report of the inclining test (Form 2086) to the plan approval office,

Consequently, Mr. Morishita's Paper is very timely and I am sure that Surveyors, whether they are experienced, or new to the subject, will find this Paper of practical use when witnessing the undertaking of inclining experiments.

May I finish by inviting the Author to comment further upon the above aspects.

To: Mr. D. V. Whittaker

The Author would like to thank Mr. Whittaker for his valuable contribution to the discussion.

It should be emphasised that, for more than two decades, LR has maintained its own standard procedures for inclining experiments. These were initially published in the "Instructions to Surveyors" but have since been updated and superseded, first by the "Code of Practice, then the "Survey Procedures Manual" and more recently the "Marine Division Survey Procedures Manual".

IACS and IMO have published guidance on conducting an inclining experiment which is basically the same as that which LR has followed for 20 years. It would therefore appear that the LR policy, which maintains the importance of the inclining experiment for stability aspects, is correct.

With reference to water ballast transfer, we have not recommended its use as the means of providing the heeling moment, since, in order to obtain correct results, the method requires special care compared with solid weight shifts. However, water ballast transfer is performed for large ships where the normal means of inclining are clearly inappropriate e.g. a 170,000t dwt bulk carrier would require approximately 500 tonnes of solid weights.

As pointed out by Mr. Whittaker, the LRTA Paper describes the detailed procedures and calculation methods of water ballast transfer when used as the means of providing the heeling moment. It should be noted that there may be some difficulty when obtaining accurate measurements of liquid weight shifts since the method, involving tank soundings or ullages, will be affected by the ship's trim and heel; however, as stated above, this method is sometimes necessary. The example shown in Appendix A of the LRTA Paper provides the reader with a detailed analysis of a water ballast transfer case.

With respect to items (i) to (vi), I would fully agree with Mr. Whittaker. Some of these concerns have indeed caused serious problems which can affect the results of inclining experiments.

From: Mr. J. D. Morley

Mr. Morishita is to be thanked for an excellent Paper.

During the presentation, Mr. Morishita said that other methods of inclining a ship would be considered. Can the Author comment as to other methods which have been accepted, since I understand that accurately weighed hatch covers of the side-rolling type have been used in the past as inclining weights on large Bulk Carriers/OBOs?

To: Mr. J. D. Morley

Only solid weight shifts and liquid weight transfer for the inclining experiment are recommended if accurate test results are to be obtained.

The use of hatch covers as inclining weights is not appropriate for the following reasons:-

(i) The hatch covers' weight cannot be accurately measured due to their size,
(ii) The accurate position of the co-ordinates of the centre of gravity (vertical, transverse and longitudinal) of covers cannot be determined by direct measurement. The centre of gravity may only be obtained by calculation from plans and the verification of its position would be difficult.

From: Mr. T. Pappas

I would like to congratulate Mr. Morishita for his very informative presentation. I would like to ask two questions:-

(i) Approximately how much time will the Surveyor normally be afforded in order to carry out an inclining experiment, for example in the cases of a small general cargo ship and a VLCC?
(ii) Does the Author think that the time required is normally available; also, can a Surveyor have full knowledge and control over what goes on and off the ship for the duration of the experiment?

To: Mr. T. Pappas

(i) The average time required to conduct an inclining experiment is:

a) Small ships: 3-4 hours,
b) Large ships: 6-7 hours.

A typical time schedule for an AFRAMAX tanker would be:

Test	Time
a) Draught readings	8.30 – 9.30
b) Supervision, tank soundings, etc	9.30 – 12.00
c) Inclining test	12.00 – 5.30

The times at which items b) and c) would be carried out will be affected by the ship's size, but item a) would not be so affected.

It should be recognised that inclining the ship by transferring liquid weights generally takes longer than that for solid weight transfers, since tank soundings/ullages are required at each shift. However, much time can also be spent shifting a large number of solid weights on large ships.

(ii) If the test is conducted in a proper manner, in accordance with the requirements in the MDSPM, the test can be completed within a reasonable time as indicated above.

The attending Surveyor should witness all measurements and readings where possible, and ensure that the data given in the final inclining experiment report is consistent with that gathered during the test. Some degree of trust must, of course, be established between the Surveyor and shipyard staff, but given that, it is believed the Surveyor will have sufficient control/ knowledge to ensure accurate results.

From: Mr. E. Karaminas

My thanks to Mr. Morishita for a very useful and practical Paper.

One cannot ignore the important opening remark from Mr. Morishita's presentation, "The inclining experiment... is the only means of accurately determining a vessel's lightweight and the corresponding VCG and LCG. ... and it provides a satisfactory basis for evaluating the ship's stability characteristics".

I agree with the above, provided the inclining experiment is carried out as part of a controlled process, such as described later on in the LRTA Paper.

My proposal to Mr. Morishita is that it may also be useful to identify specifically which hydrostatic data should be confirmed following analysis of the inclining experiment report.

May I take this opportunity to bring to the attention of Mr. Morishita the formula given by Scribanti for the correction of GZ:

$$GZ = GM \sin\theta + BM \frac{\tan^2\theta}{2} \sin\theta$$

Note: The formula is supposed to be valid for angles up to 10°.

Based on the data collected so far, could the Author comment on the validity of this formula?

To: Mr. E. Karaminas

The Author would like to thank Mr. Karaminas for his valuable contribution.

As stated in paragraph 3.4 of the LRTA Paper, normal hydrostatic data based on the level keel (zero trim) may be used for the analysis of a test report, provided the actual trim of the vessel is not more than about 1% of its length between perpendiculars (Lbp).

If the trim at the test is more than 1% of Lbp, either of the following should be used:-

(i) Trimmed hydrostatic data, corresponding to the actual trim at the test,

(ii) Bonjean data, for displacement calculation and the Lines plan to obtain actual waterplane.

The GZ formula given by Mr. Karaminas gives an accurate value of GZ for all values, provided the ship is wall-sided. It is noted that the second term has been added, compared with the usual expression for GZ at small angles, viz. $GZ = GM\sin\theta$.

For a ship with a BM of 50m, the value of the second term would be:

a) 0.0001 at 1 degree,
b) 0.0004 at 1.5 degrees,
c) 0.0010 at 2 degrees.

In view of the above, the effect of the second term at small angles is not considered to be significant and may indeed be negligible.

From: Mr. V. Papageorgiou and Mr. P. R. Nichols (LR Piraeus)

We would like to congratulate the Author on a clear and well illustrated Paper, which should be very useful to Surveyors.

There are two questions which we would like to ask:-

(i) With the increasing number of multi-hull vessels, e.g. catamaran high speed ferries etc., are there any areas of the inclining experiment procedure which become more critical than would normally be the case for a monohull?
(ii) Some shipyards have experimented with asymmetric designs of monohulls, asymmetric sterns etc. In such cases, when the transverse centre of buoyancy may not be exactly on the vessel's centreline, and could move as the draft changes, are there any modifications which should be incorporated into the procedure, or would any such effects be considered too small?

To: Mr. V. Papageorgiou and Mr. P. R. Nichols (LR Piraeus)

(i) The principle of conducting an inclining experiment is not changed irrespective of ship size and type. With respect to multi-hull vessels, which predominantly fall into the category of small vessels, even a small effect on the test results will be vital, therefore, careful attention should be drawn to the following:-

    a) The ship should be held by lines at the bow and stern centreline in order to eliminate the heeling action caused by the transverse force of mooring ropes,
    b) Pendulum positions should be arranged at sheltered locations so that the effects of wind on pendulum readings is minimised,
    c) The use of U-tubes in the summer season is not recommended due to expansion caused by high atmospheric temperatures,
    d) Strength of the deck spaces where shifting weights are loaded should be checked by the builders before the test,
    e) The minimum number of draught readings should be ten,
    f) The missing weights, i.e. the weights of those items still to be added to the ship to complete it, should preferably be zero.

(ii) The inclining test procedure for conventional ships may also be applied to asymmetric ships. If necessary, the effect of an offset transverse centre of buoyancy etc. should be considered when analysing the test results.

Acknowledgements
I would like to express my thank to Messrs. C.M. Magill, D.V. Whittaker and A.J. Williamson who gave useful advice and suggestions whilst preparing the LRTA Paper.

FIGURES

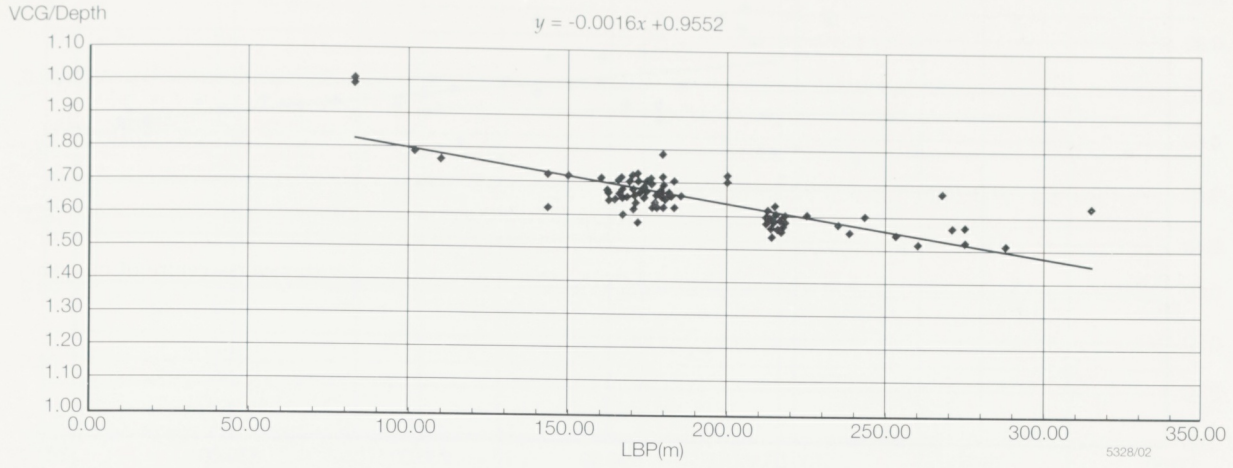


Figure 23.1
VCG for Bulk Carrier

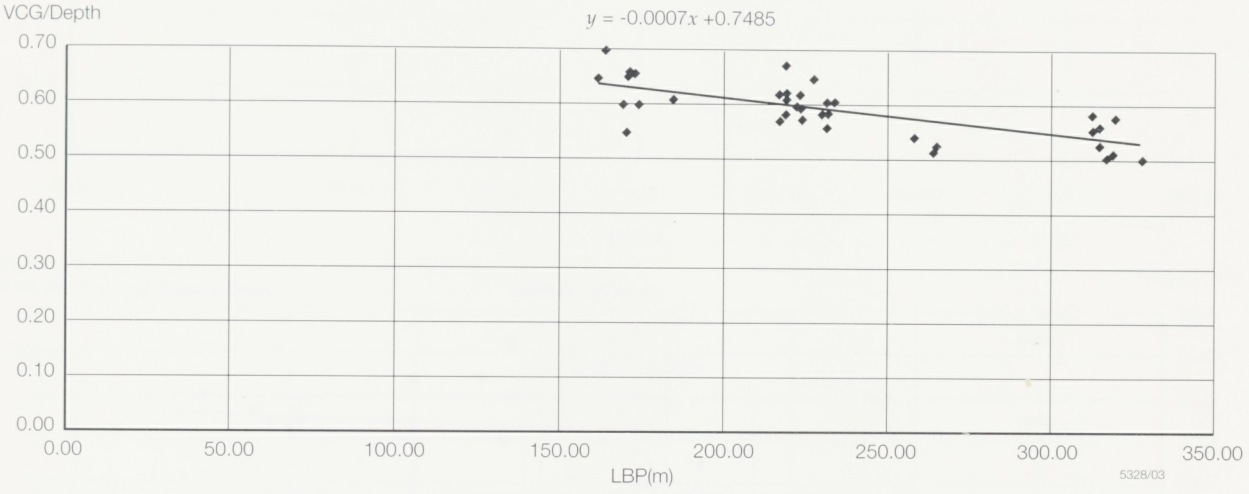


Figure 23.2
VCG for Oil Tanker

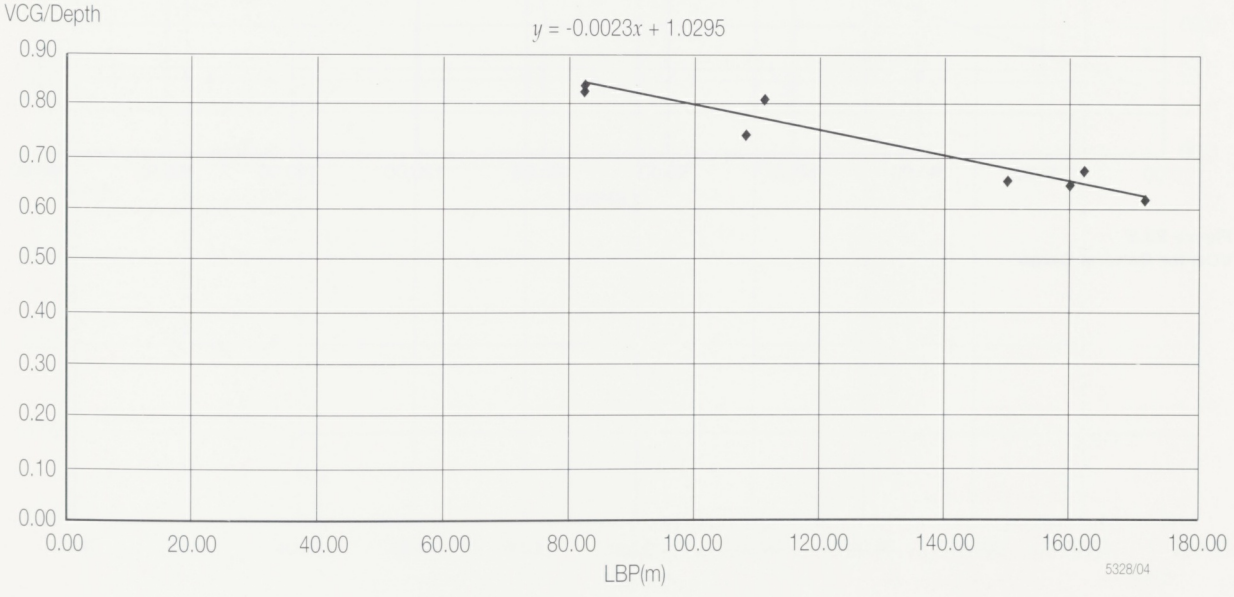


Figure 23.3
VCG for Chemical Tanker

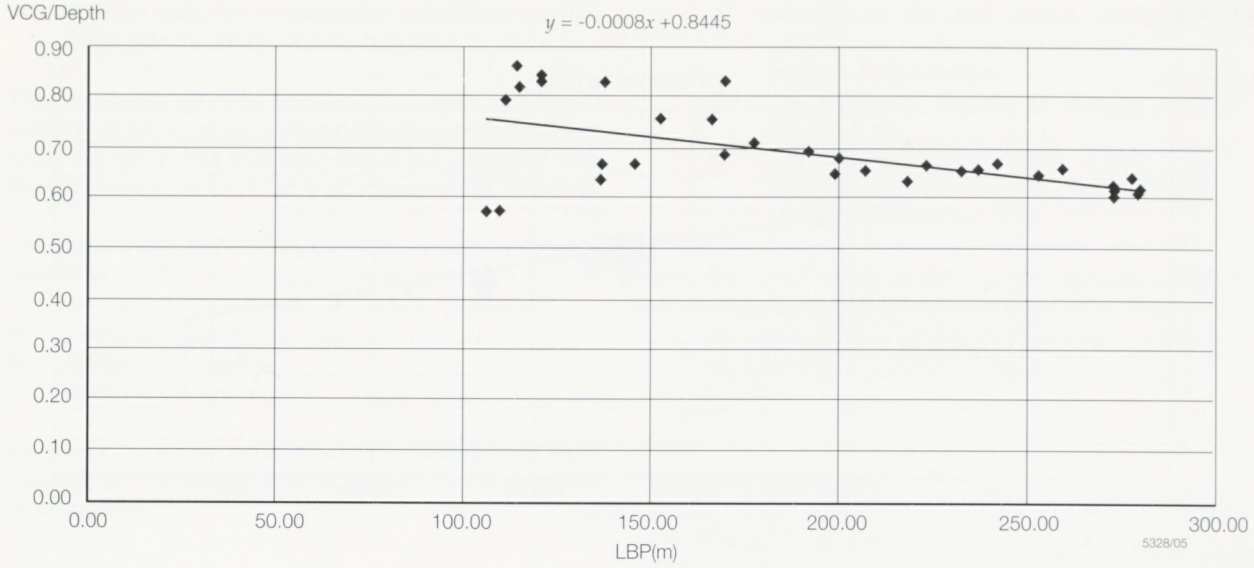


Figure 23.4
VCG for Container Ship

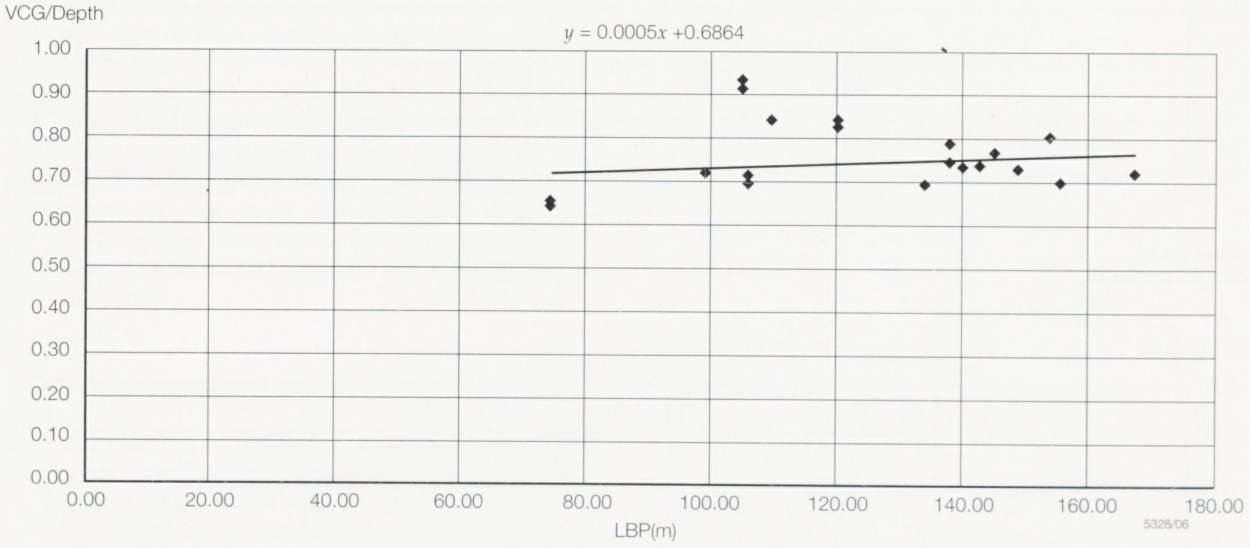


Figure 23.5
VCG for General Cargo

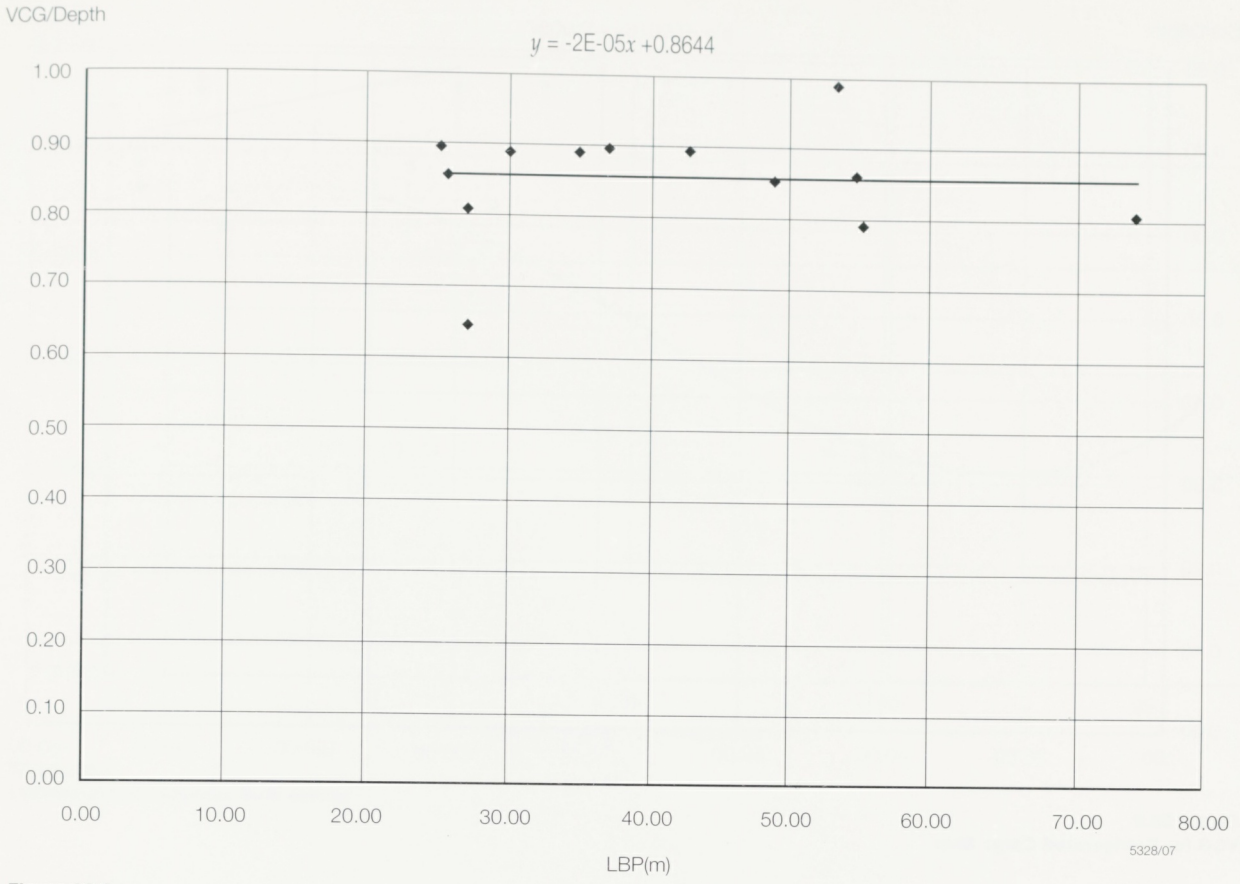


Figure 23.6
VCG for Tug and Supply Boat

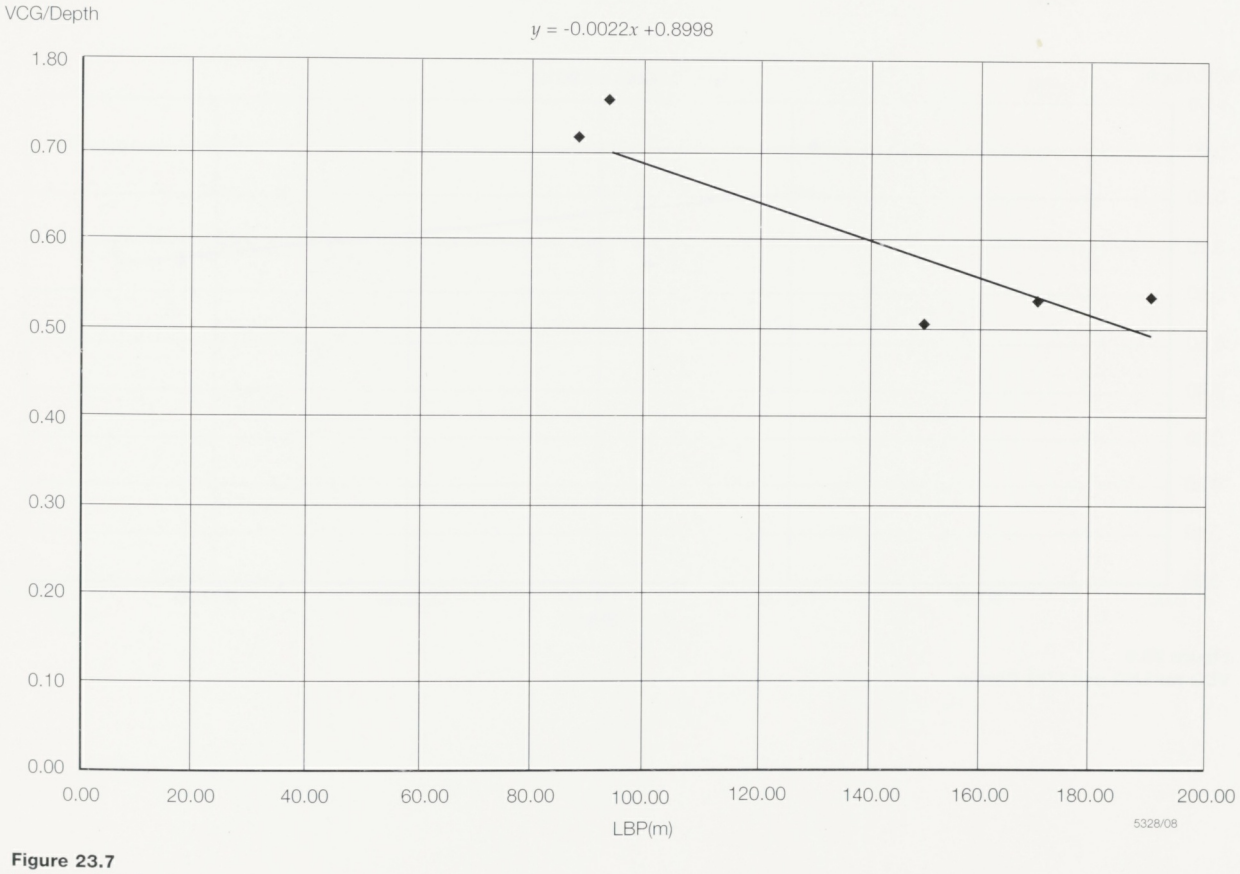


Figure 23.7
VCG for Vehicle Carrier

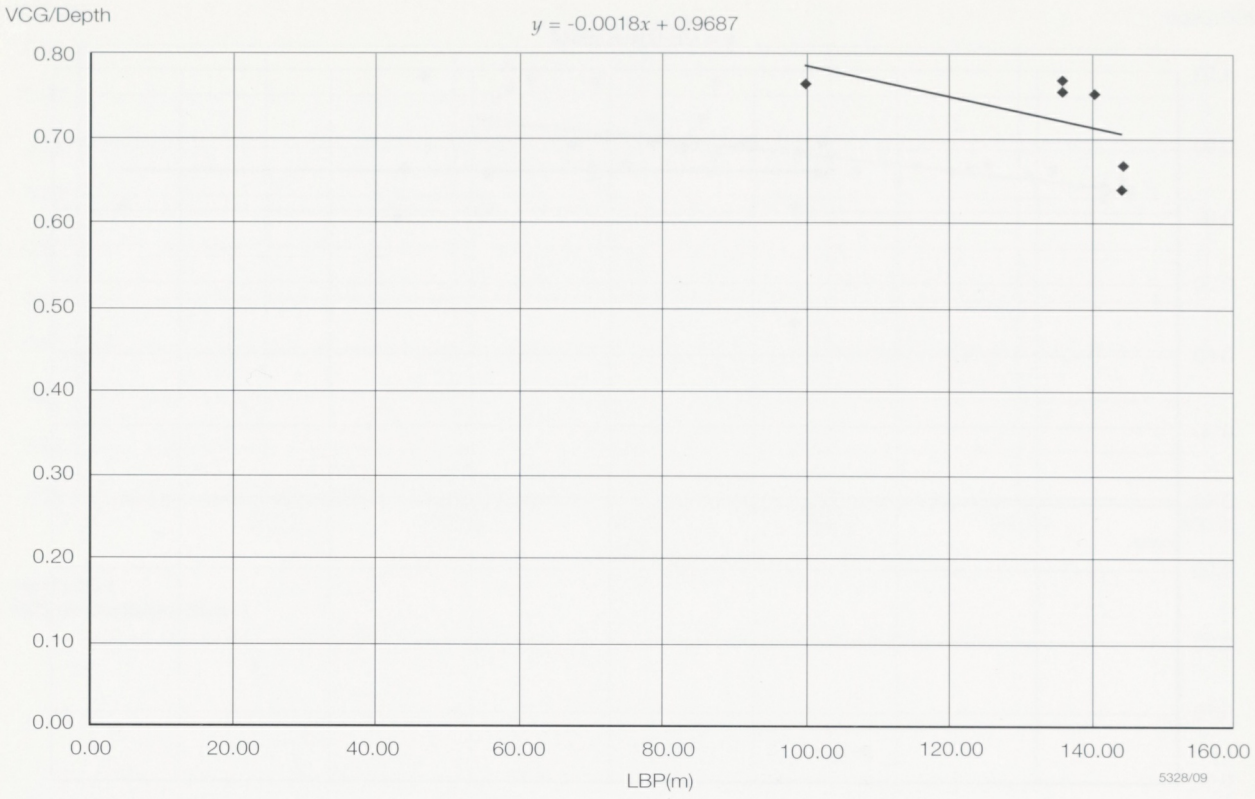


Figure 23.8
VCG for Refrigerated Cargo Ship

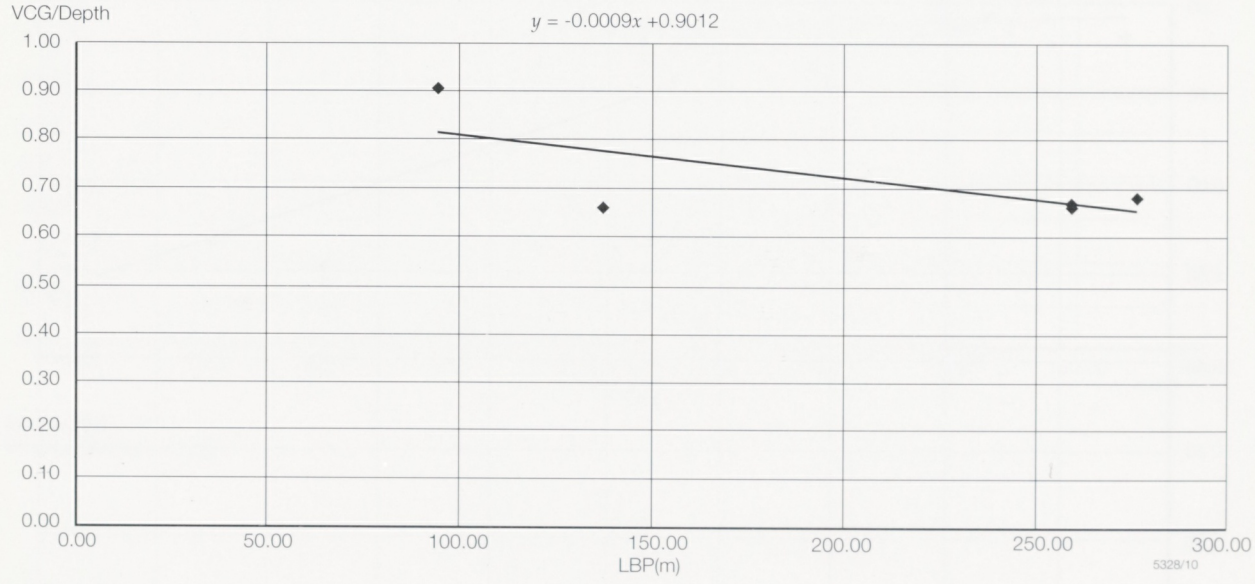


Figure 23.9
VCG for LNG and LPG Carrier

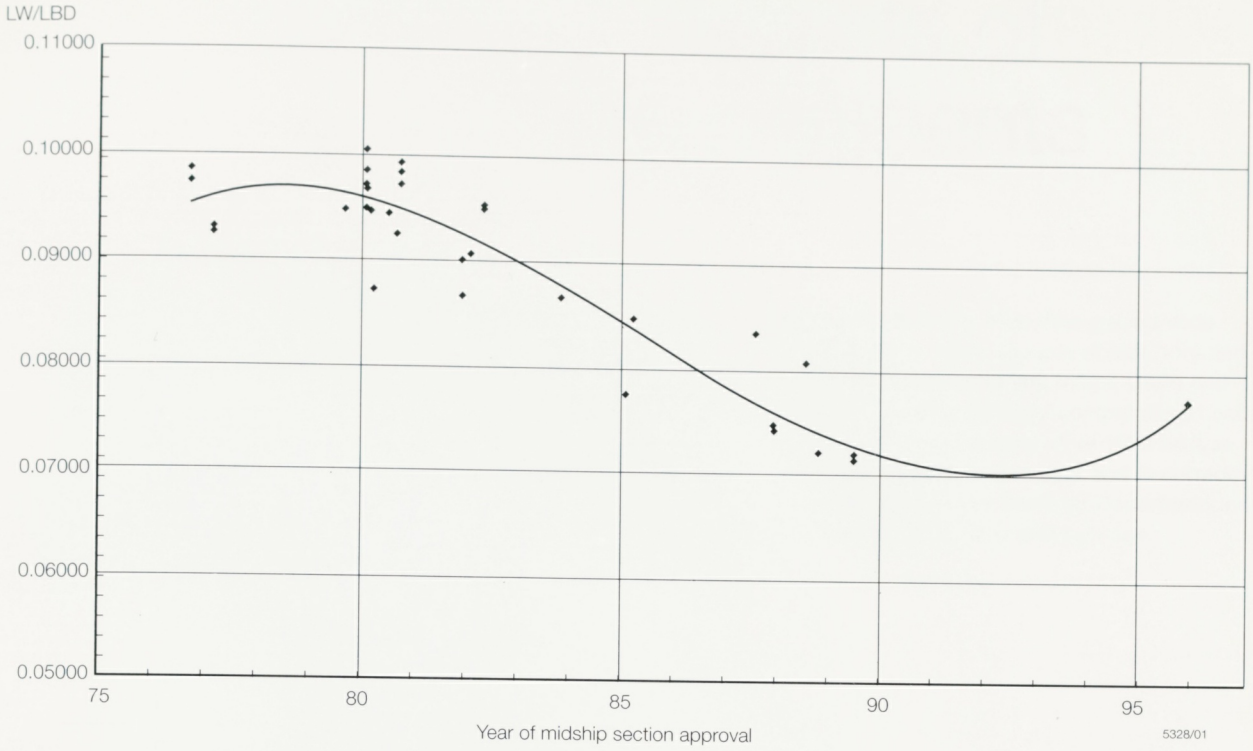


Figure 24.1
Lightweight of Panamax Bulk carrier

Practical aspects of inclining experiments

by F. Morishita



Mr. Morishita graduated from Hiroshima University, Japan as a Naval Architect in 1969 and worked briefly thereafter at Ujina/ Kanawa Dockyard, Hiroshima where he was involved in basic ship design. In 1980 he joined Lloyd's Register as a probationary Ship Surveyor and was appointed Surveyor in the International Conventions Department, Yokohama in 1982.

Since that time Mr. Morishita gained wide experience in many aspects of statutory and computer work, including Intact, Grain and Damage stability, Tonnage computation, Load Line and Safety Equipment. In 1993 he was promoted to Senior Surveyor and is currently working in Statutory Services Department on all aspects of stability and tonnage.

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Synopsis

The Paper describes the practical aspects of the inclining experiment or test for the guidance of the surveyors who will check the test procedure and attend the test and the plan approval surveyors who will examine the inclining test report submitted by the builders. The Lightship Data contained in Appendix B has been prepared for guidance/reference.

1 Introduction

The inclining experiment or test is an essential part of the new construction or conversion of a ship or floating unit as it is the only means of accurately determining a vessel's lightweight and the corresponding vertical (V.C.G.) and longitudinal (L.C.G.) position of it's centre of gravity. This Paper is intended to provide practical guidance to the surveyor in order to minimize inaccuracies during the test and to ensure that the information derived from the inclining experiment provides a satisfactory basis for evaluating the ship's stability characteristics. The results of the inclining experiment are used to prepare the final Loading Manual.

It is a requirement of Regulation 22, Part B, Chapter II-1 of SOLAS 1974 that every passenger ship regardless of size and every cargo ship having a length, as defined in the International Convention on Load Lines 1966, of 24 m and upwards, is to be inclined upon its completion and the elements of its stability determined.

The inclining test of an individual ship, or class of ships especially designed for the carriage of liquids or ore in bulk, may, however, be dispensed with when reference to existing data for similar ships clearly indicates that, due to the ship's proportions and arrangements, more than sufficient metacentric height (GM), will be available in all probable loading conditions.

When an accurate inclining test is not practical, for example, on some high speed craft, the lightship displacement and position of its centre of gravity is to be determined by a lightweight survey and accurate calculation.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the master, amended stability information is to be provided. A ship would normally be re-inclined where the anticipated change in lightship weight exceeds 2% or where a large rise in VCG is expected.

Appendix A of the Paper includes a worked example to determine the lightship particulars of a vessel following an inclining experiment in which water ballast transfer has been used to incline the vessel.

Appendix B includes the lightship particulars of about 400 ships built in Japan, Korea and China. These lightship particulars, for example lightweight, V.C.G. and L.C.G., have been summarized on the basis of the ships' principal dimensions.

The procedures indicated in this Paper are intended to supplement Lloyd's Register's procedures for inclining experiments and in no way replace those requirements.

2 General

It should be recognised that an inclining experiment and the vessel's lightship condition is very sensitive to the effects of tight mooring ropes, undetected slack water on board, windage effects etc. and therefore the attending surveyor must pay careful attention before and during the experiment to obtain accurate results from the experiment.

As a general principle, each new ship, or the first and each subsequent fifth ship in a series at each building yard is to be inclined, with a lightweight check carried out on the remaining sister ships. Certain flag administrations may require the first vessel in a series building to their flag to be inclined regardless of previous sisters.

If dispensation from the requirement to conduct an inclining experiment is required in the case of a sister to a ship already inclined, the builder is to make written application to the local office.

- The local office is to forward the application through the authorised plan approval office to Headquarters for consideration. The local surveyor is to indicate whether or not, in his opinion, the ship is suitable for dispensation from the requirement to conduct an inclining experiment and should confirm that the ship, being in a series, is similar to the lead ship in geometry, anticipated lightweight and lightweight distribution.
- Where a lightweight survey is conducted, the V.C.G. of a previously inclined sister ship may only be used provided it is verified by the survey that the lightweight and L.C.G. compare, within acceptable limits. A report of the lightweight check is to be incorporated into the final stability manual, together with a copy of the report of the inclining experiment for the lead ship.

The surveyor witnessing the inclining experiment or lightweight check must be satisfied that the procedures have been followed and the data obtained correct. If for any reason it is considered that a successful test can not be held, for example due to poor weather, state of the ship etc., then the test should be postponed. As soon as the inclining experiment or lightweight check report is available, the surveyor is to verify that the information contained therein is consistent with the results obtained during the test and forward the report to the authorised plan approval office together with sufficient basic data to enable the plan approval office to undertake an independent check of the final results. The surveyor should also forward a signed declaration form in respect of the inclining test or lightweight check.

When a lightweight survey is required, it is to be carried out on completion of the ship by the measurement of draughts, recording the specific gravity of the water and estimate of weights on and off. The L.C.G. of the lightship must also be calculated.

3 Preparation for the test

3.1 The Inclining Test Condition

The ship is to be as near to completion as possible and the equipment used by the shipyard on board is to be limited to the utmost extent possible. Prior to the inclining test, lists of all items which are to be added, removed, or relocated are to be prepared. These weights and their locations are to be accurately recorded. As a guide, the total value of missing weights is not to exceed two per cent of the lightship displacement, and surplus weights, including liquid ballast, is not to exceed four per cent. For smaller vessels, higher percentages may be allowed.

3.2 On notification to the Society

The surveyor should impress upon the builders the need to give adequate notice of a test and request them to supply the following information:

(a) Proposed location, date and time
(b) Proposed mooring arrangements
(c) Anticipated state of the ship at the time of the test
(d) Anticipated load condition
(e) Type of inclining ballast to be used
(f) Proposed heel indicators
(g) Location of central station, inclining test weights, and pattern of weight shift
(h) Maximum expected angle of heel
(i) Anticipated tank condition, viz., whether empty, full or partially filled.

The builder is to provide a written procedure for the inclining experiment or lightweight check which the surveyor should agree ensuring that it follows that given in LR's Ship Division Survey Procedure Manual (SDSPM). In the following cases, the procedure is to be submitted to the authorised plan approval office for acceptance, prior to the inclining experiment:

- For passenger ships.
- Where it is proposed to use liquid transfer to incline the ship.
- Where the proposed procedures differ from standard practice.

3.3 Mooring arrangements and environmental conditions

Mooring lines should be free of any transverse tension during the reading after each weight shift. No external moments shall be brought upon the ship (from mooring lines, quays etc.). If possible, the ship should be located in a calm, protected area free from external forces.

When it is intended to conduct the test at or near low water, the surveyor should ascertain that a sufficient depth of water will be available to prevent the ship from touching the bottom during the test. If this is likely to cause a problem, the test should be conducted at high tide or the ship moved to deeper water.

The combined adverse effect of wind, current and sea may adversely affect results due to:

- inability to measure draught accurately
- excessive or irregular oscillations of the pendulums or U-tubes
- variations in superimposed heeling moments

The ship should be held by lines at the bow and stern, attached to temporary pad eyes installed as close as possible to the centreline of the ship and as near the water line as practical. If temporary pad eyes are not feasible then lines can be secured to bollards and/or cleats on the deck (see Plates 1 and 2). This arrangement requires that the line be slackened when the ship is heeled away from the dock. The preferred arrangement is with the ship lying in a slip or dock where it can be moored as shown in Figure 1.1. In this case, the lines can be kept taut to hold the ship in place, yet allow unrestricted heeling. Note, however, that wind and/or current may cause a superimposed heeling moment to act on the ship throughout the test. For steady conditions this will not affect the results. Gusty wind or uniformly varying wind and/or current will cause these superimposed heeling moments to change, which may require additional weight shifts to ensure a valid test. The need for additional weight shifts can be determined by plotting pendulum readings as they are obtained.

Where the ship can be moored on one side only, it is good practice to supplement the bow and stern lines with two spring lines in order to maintain positive control of the ship, as shown in Figure 1.2. The leads of the spring lines should be as long as practicable. Cylindrical camels should be provided between the ship and the dock. All lines are to be slack, with the ship free of the pier and camels, when taking readings during the experiment.

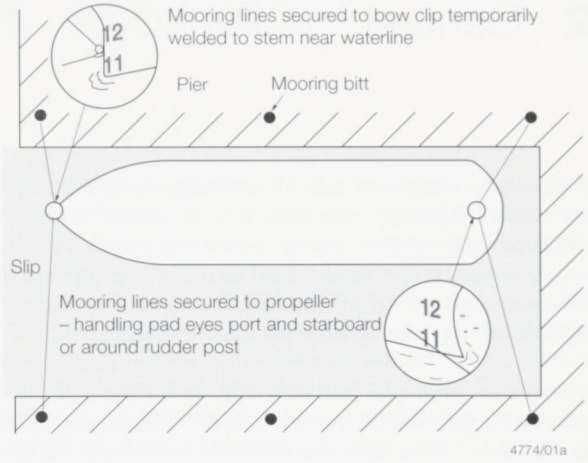


Figure 1.1 – Lying in a slip/dock

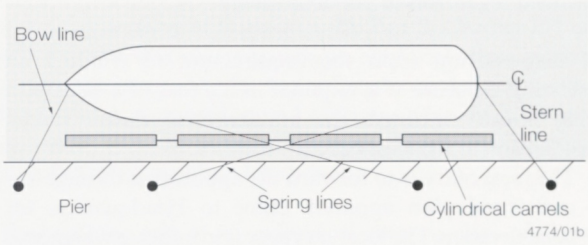


Figure 1.2 – Moored to one side only

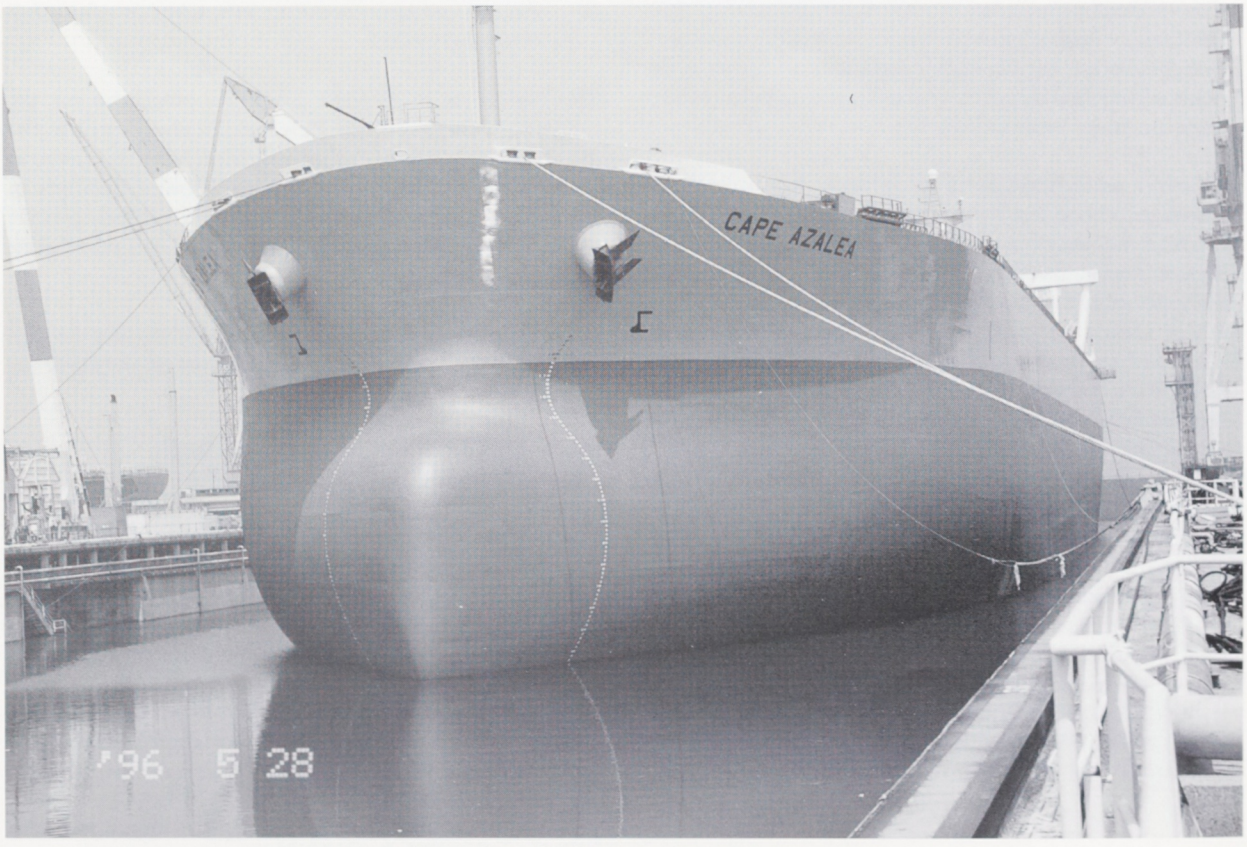


Plate 1 – Forward mooring lines



Plate 2 – Aft mooring lines

Alternative mooring arrangements may be considered if these are submitted to the authorised plan approval office for review prior to the test. Such arrangements should ensure that the ship will be free to list without restraint for a sufficient period of time to allow the pendulums to damp out motion so that accurate readings can be recorded.

If a floating crane is used for handling inclining weights, it must not be moored to the ship.

3.4 Trim

Excessive trim by the stern should be avoided and trim by the head is not recommended. It is acceptable to use hydrostatics based on level keel where the actual trim does not differ by more than about 1 per cent of the length between perpendiculars (Lbp). The waterline during the inclining test should not coincide with sharp changes in the cross-sectional area of the ship.

3.5 List

As far as practicable the ship should be upright at the commencement of the test. A small initial list is acceptable but this should not exceed 0.5 degrees.

Where an initial list is present, it should be ensured that the first weight shift takes the ship through the upright position, otherwise any correction made to account for the movement of free liquid surfaces may produce an inaccurate result.

3.6 Tanks and free surface

3.6.1 General

The information given to the surveyor regarding the disposition and capacity of all tanks on the ship, should also indicate the location of the appropriate air and sounding pipes to these spaces.

The number of slack tanks should normally be limited to one port/starboard pair or one centreline tank of the following:

- fresh water reserve feed tanks;
- fuel/diesel oil storage tanks;
- fuel/diesel oil day tanks;
- lube oil tanks;
- sanitary tanks; or
- potable water tanks.

The builders should provide calibration curves or tables appropriate to those tanks likely to be full or partly full during the test.

3.6.2 Free surface

If there are liquids on board the ship when it is inclined, whether in the bilges or in the tanks, it will shift to the low side when the ship heels. This shift of liquids will exaggerate the heel of the ship. Unless the exact weight and distance of liquid shifted can be precisely calculated, the metacentric height (GM) calculated from the incline test will be in error. Free surface should be minimized by either emptying the tanks completely by stripping with portable pumps or by hand, or by completely filling the tanks so that no shift of liquid is possible. All bilges should be dry.

When tanks must be left slack, it is desirable that the sides of the tanks be parallel vertical planes and the tanks be regular in shape (i.e. rectangular, trapezoidal, etc.) when viewed from above, so that the free surface moment of the liquid can be accurately determined. For example, the free surface moment of the liquid in a tank with parallel vertical sides can be readily calculated by the formula:

Free surface moment (m-tonnes) = $(l\ b^3/12) \times \rho$

where: l = length of tank (m)
b = breadth of tank (m)
ρ = density of liquid in tank (tonne/m^3)
(ρ can be measured directly with a hydrometer)

Free surface correction (m) =
Sum [FSM(1) + FSM(2) + ... + FSM(x)]/Displacement

where: FSM = free surface moment (m-tonnes)

Free surface correction is independent of the height of the tank in the ship, location of the tank, and direction of heel. As the width of the tank increases, the value of free surface moment increases by the third power. The distance available for the liquid to shift is the predominant factor. This is why even the smallest amount of liquid in the bottom of a wide tank or bilge is normally unacceptable and should be removed prior to the inclining experiment. Insignificant amounts of liquids in V-shaped tanks or voids (e.g. a chain locker in the bow), where the potential shift is negligible, may remain if removal of the liquid would be difficult or would cause extensive delays.

The correction to the GM calculation for free surface effects in part filled tanks, is to be based on the liquid level in the tanks and not the tank's maximum value of free surface moments.

3.6.3 Slack tanks

The liquid level of any partly filled tank must be such that the free surface effect can be accurately determined. Partly filled deep tanks should be 20% to 80% full and double bottom tanks 40% to 60% full to ensure that a significant change in the dimensions of the free surface does not occur during inclining. Where tank contents are to be of high viscosity, consideration should be given as to whether they should be heated or not for the test. If heated, free surface corrections would need to be applied in the analysis of the test results. Communication between tanks should never be allowed, i.e. cross connections should be closed.

3.6.4 Pressed up tanks

Such tanks are assumed to be completely full with no pockets or voids, i.e. 100% full. (The 98% full condition normally accepted as 'full' for operational reasons is not acceptable for an inclining experiment). Tanks required to be pressed up should be filled in advance of the test until the tank is completely filled. Topping up of a tank should be carried out slowly and the tank ullage checked at intervals. An example of a tank which would appear to be 'pressed up' but would actually contain entrapped air is shown in Figure 2.

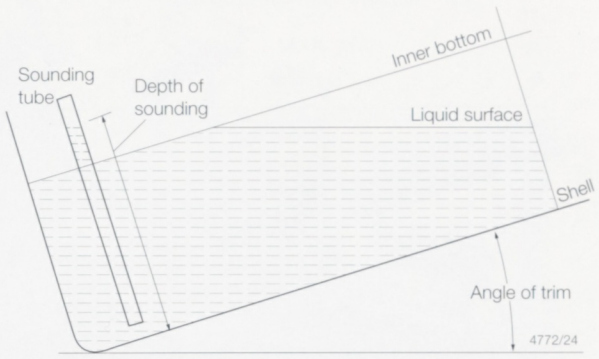


Figure 2 – Sounding of tank

3.7 Tests weights

The means of inclining the ship is to be specified. Where solid weights are used, each weight is to be compact, impervious to water and of such shape that its centre of gravity may be accurately determined. It is recommended that no fewer than four weights (or sets of weights) be used, each approximately equal in magnitude and initially disposed on either side of the ship as far from the centreline as practicable. All weights should be recently certified, and bear means of identification. Positioning of all inclining weights on one side of the ship should result in a minimum heel angle of about 1° up to a maximum of 4° from upright, depending upon ship type and size.

To ensure that the test may be completed within a reasonable time, the surveyor should verify that adequate means are available to shift the inclining weights expeditiously and so reduce the risk of the test being affected by appreciable changes in wind and/or tide.

Precautions should be taken to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then a structural analysis should be performed to determine if existing framing can support the weight.

The weights should be positioned as far outboard as possible on the upper deck. The positions of the weights should be marked and arrangements made to ensure that they can be placed back in their exact original positions as the test progresses (see Plates 3 and 4).

The transverse movement of the weights should be arranged so that there is no longitudinal change in the position of each weight which would affect the ship's trim.

Notwithstanding the comments in the SDSPM, water ballast is being utilised more and more for liquid weight transfer, particularly for very large ships where normal means of inclining are clearly inappropriate and also large passenger ships where the deck space of sufficient strength may not be available.



Plate 3 – Shifting weights on deck

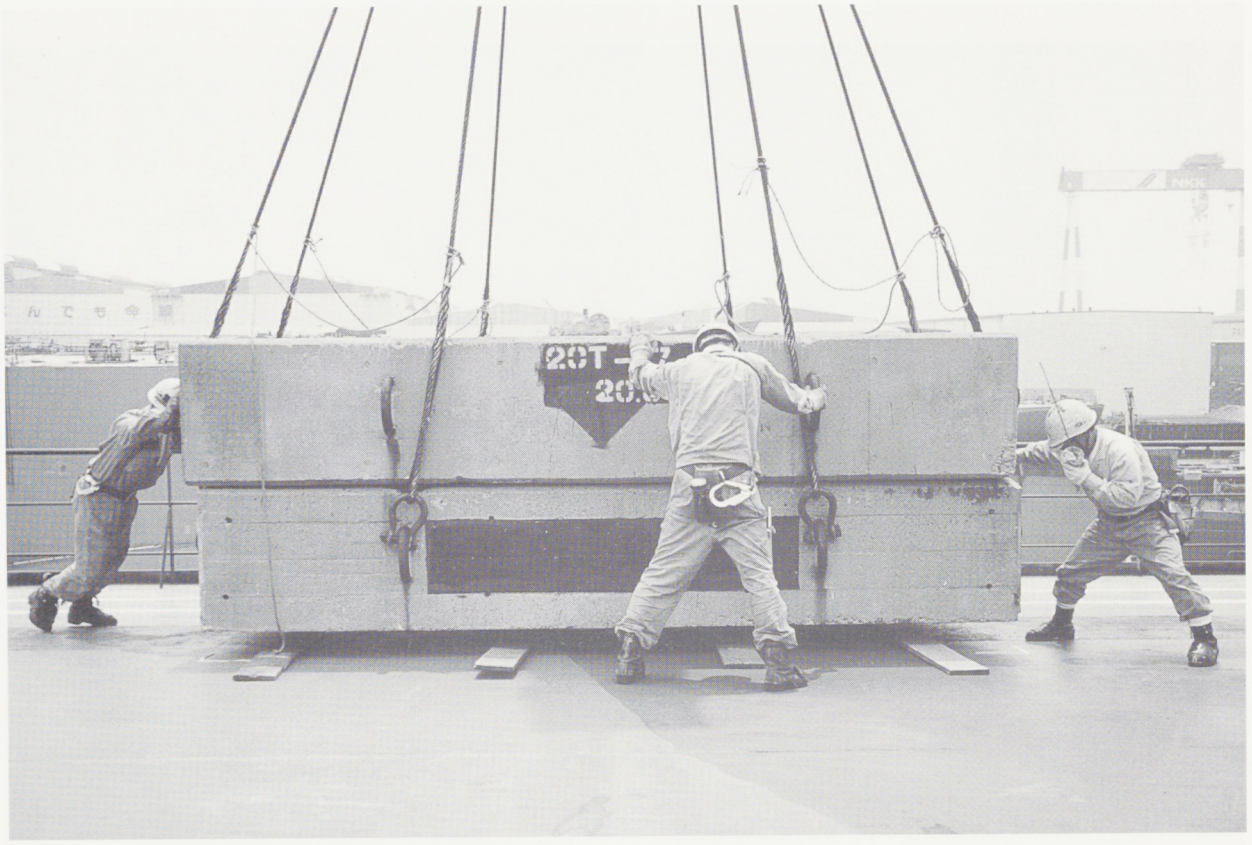


Plate 4 – Positioning of weight

Where water transfer is to be used;

(i) Inclining tanks should be wall sided and free of large stringers (which may create air pockets).

(ii) The transfer should take place between tanks directly opposite one another to maintain the ship's trim.

(iii) Where gravity transfer is adopted, two tanks each port and starboard should be used with adequate head between each pair of tanks port and starboard to provide several movements.

(iv) The specific gravity of the transferred water should be checked.

(v) The pipe lines used for shifting the water should be full on commencement in order that an accurate quantity of shifted water can be obtained.

(vi) The isolating valves should be checked for tightness and strict valve control maintained during test.

(vii) Ullage/sounding boards or external tubes should be fitted to enable the level of water in each tank involved to be measured before and after each shift and recorded in the test report.

(viii) If necessary, final calculations are to take account of the change in VCG during the test due to the transferred layers of water.

(ix) The weight and centre of gravity of the shifted water should be determined considering the ship's heel and trim.

(x) The means of calibration of the inclining tanks should be stated and ullage tables provided.

4 Final preparations immediately before the test

4.1 Supervision and initial preparations

The following information should be available at the time of the stability test as necessary:

- General arrangement drawing
- Tank capacity plan
- Hydrostatic curves
- Draught marks' locations.

The surveyor should be satisfied that the mooring arrangements adopted take proper account of depth of water under the hull, wind speed and direction, tidal current, propeller wash from other ships, shoreside discharges, etc.

He is to accompany representatives of the owner/builder in a detailed tour of the ship. All spaces are to be inspected, and keys made available for access to closed areas.

In the course of the tour, the surveyor should ensure that a record of the location and weight of those items which will be considered in the calculation of the lightweight of the ship is being made and be satisfied with the accuracy of such a record.



Plate 5 – Tank sounding

Bilges should be dry and there should be no slack water on tank tops or decks.

All empty compartments are to be open, clean and dry.

Tanks are to be well ventilated and gas free. A certified marine chemist's certificate, certifying that oil and chemical tanks are fit for entry should be made available. LR safety procedures are to be followed for safe entry into tanks.

Any hanging weights or loads are to be efficiently secured. The ship's lift/s is/are not to be used.

Boilers, sanitary and cooling systems, etc., should be at or near their normal working levels.

The draining of tanks intended to be empty during the test should be completed by portable means, or by hand where necessary, when this cannot properly be achieved by the ship's own pumping system.

Each tank is to be verified for content by sounding (Plate 5) and visual inspection where practicable. The specific gravity of the contents is to be recorded.

Personnel allowed on board should be limited to the minimum required for the test and will, generally, consist of persons required for the measurement of pendulum deflections, handling of the inclining weights, and control of the test. The person in charge of the inclining test should be identified.

The gangway is to be removed before the test commences and shore connections (other than those required for mooring and essential power lines, hoses, etc.) are to be disconnected. All connections retained are to remain slack throughout the test.

Builders' tools, equipment and other non-lightship items should be reduced to the absolute minimum.

Any appreciable quantities of snow or ice must be removed from the ship before the test.

If the inclining test is carried out at low water, checks should be made to ensure that the ship is not aground.

4.2 Draught readings

A suitable boat with a low freeboard is to be provided so that the draughts of the ship being inclined may be accurately measured. The position of the draught marks should have been checked previously on the building berth or in a dry-dock (see Plates 6 and 7).

Suitable equipment, such as a handheld type magnet, by which the position of the draught measuring boat may be kept steady, should be provided by the builders.

Draughts should be read immediately before and, if necessary, after the test and the surveyor should witness all such readings. These will also be used to determine initial heel and hog/sag, if any. On completion of the weight shifts, the draughts may be checked again, if considered necessary, to ensure that no change in condition has occurred during the test.



Plate 6 – Boat for draught measurement

A typical draught reading gauge is shown in Figure 3. The length of tube under water should be sufficient to minimize any effect of wave motion when measuring the draught. A sufficient number of draught readings should be taken to obtain correct results since accuracy of the lightweight will depend on these readings.

The surveyor should confirm by sight the draught at the mark in order to verify the measurement given by the draught gauge.

The mean draught (average of port and starboard reading) should be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot should yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the draughts should be retaken.

The specific gravity of the flotation water should be determined at this time. For the accurate assessment of its specific gravity using a hydrometer (plate 8), sufficient samples of dock water are to be taken at suitable locations and depths and not merely surface water, which could contain fresh water from the run off of rain. The hydrometer, which should be checked in fresh water before use, is placed in the water sample and the specific gravity recorded. For large ships, it is recommended that samples of the flotation water be taken forward, midship, and aft and the readings averaged. For small ships, one sample taken from midships should be sufficient.

The temperature of the water should also be taken and the measured specific gravity corrected for deviation from the standard, if necessary. If the specific gravity is determined at the inclining experiment site, a correction to water specific gravity is not necessary. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is done at the office).

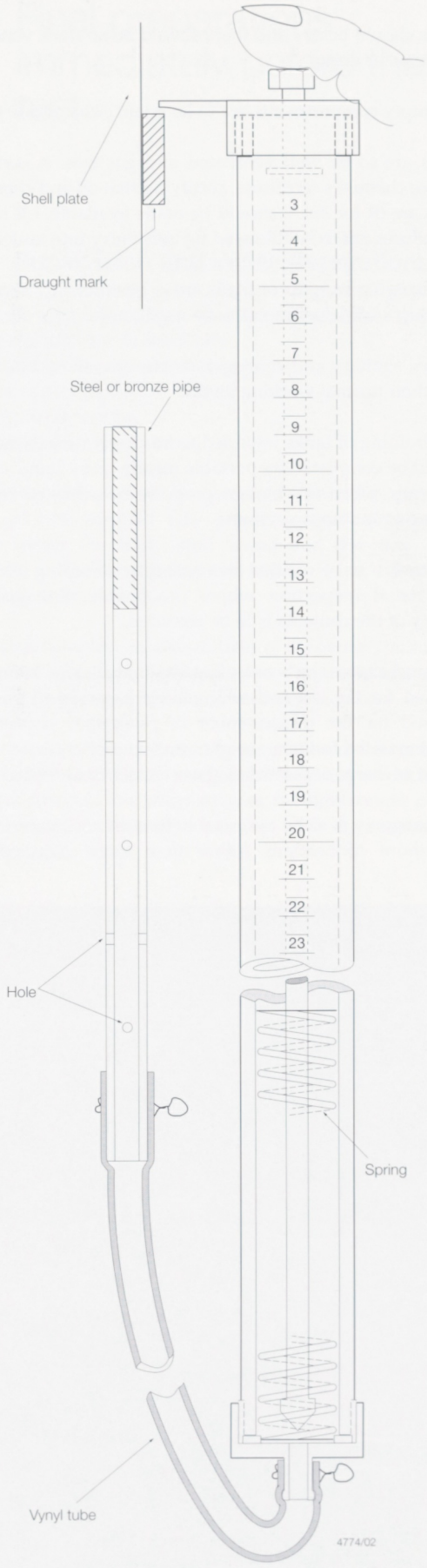


Figure 3 – Draught reading gauge



Plate 7 – Draught measurement using draught gauge



Plate 8 – Hydrometer

5 During the test

5.1 Control station

A sheltered space on board is to be allocated as a control station which should be reasonably accessible to all deflections measuring staff and handlers of the inclining weights. The person in charge of the test should be located at the control station and have complete control over all personnel involved in the test.

Personnel are to be instructed to remain in their assigned positions while pendulum readings are being taken and a check is to be made that all mooring lines, etc., remain slack during the test.

There should be efficient two-way communications between the person in control and;

- the weight handlers;
- each pendulum or deflection recording station;
- the mooring attendants.

5.2 Measurement of heel

At least two pendulums are to be suspended at separate, sheltered locations clear of surrounding structure which could affect their motion. Pendulum lengths are to be as great as practicable so as to provide an overall anticipated deflection of at least 150 mm either side of the initial position. It is recommended that pendulums should be between 4 and 6 metres in length. They are to be measured from the point of suspension to the deflection recording batten. A typical arrangement is shown in Figure 4.

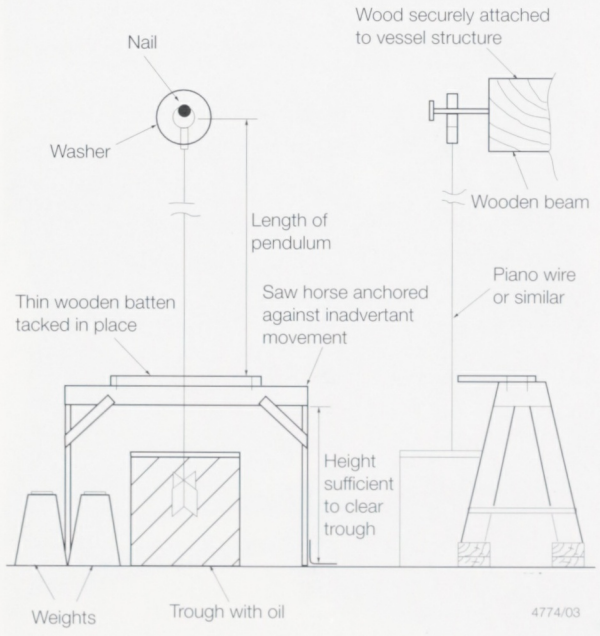


Figure 4 – Pendulum

A smooth wood recording batten (or acceptable equivalent) is to be firmly attached to a rigid trestle at the lower end of each pendulum. A trough containing a suitable damping fluid (oil has better damping properties than water) is to be arranged at the lower extremity of each pendulum. The surveyor is to ensure that the trough is large enough so as to prevent contact between the pendulum and the sides and bottom of the trough during the test. The trough should be secured against accidental movement.

A U-tube arrangement is acceptable as a means of measuring the test heel angles. However, the surveyor should ensure that the system is free from air locks, etc., to preclude inaccurate readings. The tube should be open-ended, of clear plastic and of such diameter that readings will not be affected by capillary effects and clamped on graduated measuring boards. The tube should be located as far outboard as possible and extend vertically to such a height that no fluid will overflow during the test. The liquid in the tube should preferably, be coloured. A typical arrangement is shown in Figure 5.

To obtain the measured mean deflection, the mean of 10 readings of the pendulum/U-tube's deviation is to be made.

The use of a stabilograph is also acceptable provided the calibration of the instrument is checked beforehand. A trace of the recorded heel pattern should be included in the test report. The principal of a stabilograph is shown in Figure 6.

Where either of the alternative methods of U-tubes and stabilograph are proposed, a single additional pendulum must also be used to provide an independent check on the measured deflections.

5.3 Weight shifts

5.3.1 Solid weight shifts

Following the initial zero reading, the experiment should involve at least eight weight movements. The example below shows the movement of four weights (numbered 1, 2, 3 and 4):

Shift	Movement	
	Port	*Starboard*
Initial	2 4	1 3
1	4	1 2 3
2		1 2 3 4
3	1	2 3 4
4	1 3	2 4
5	1 2 3	4
6	1 2 3 4	
7	2 3 4	1
8	2 4	1 3

After each shift, the pendulum readings are to be registered on the recording battens, each deflection (taking the average of say 10 swings) being measured from the previous reading.

The positions of the inclining weights should be marked on the deck to ensure consistency in placement throughout the test. The overall transverse shift distance is to be as great as practicable, and appreciable changes in longitudinal or

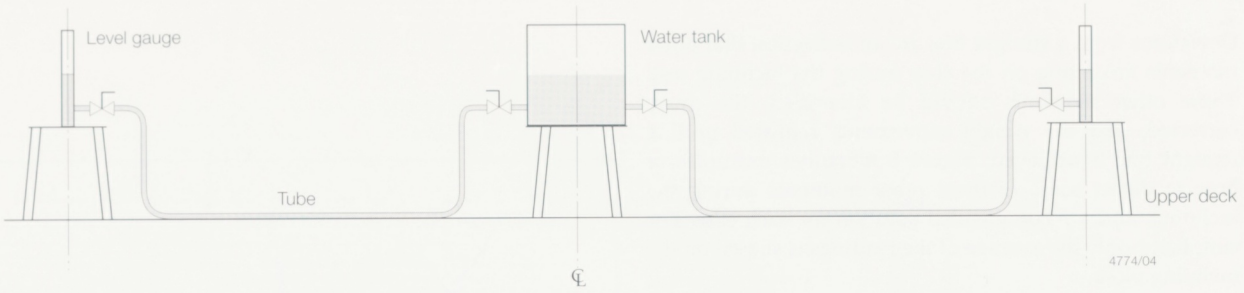


Figure 5 – U-tube

vertical position when moving weights from port to starboard and vice versa are to be avoided.

5.3.2 Liquid weight shifts

Liquid weight transfer is to take place between tanks directly opposite one another. The sounding/ullage of these tanks is to be recorded before the test commences and after each shift so that the volume, centre of gravity and free surface moment of the tanks can be determined using tank calibration data with trim and heel correction.

The volume and moments of heeling, vertical shift and free surface of the liquid transferred at each shift are determined by the difference between the present and previous shifts. The heeling and vertical shift moments may be calculated by multiplying the weight of liquid transfer by centre of gravity.

It should be noted that the free surface moment of the tanks is not constant during the inclining.

The typical procedure and calculation method of a water ballast transfer and combination of tanks for a bulk carrier is shown in Appendix A.

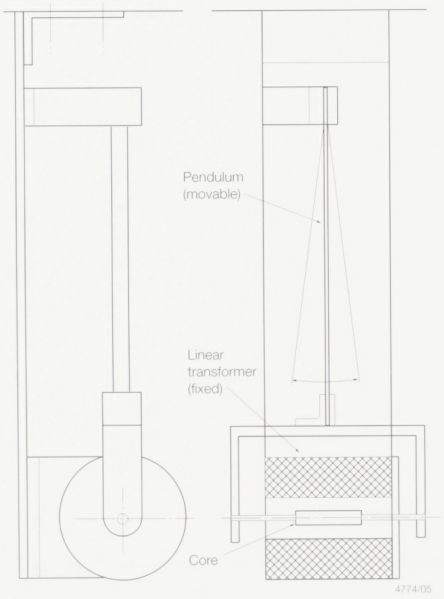


Figure 6 – Principal of a stabilograph

5.3.3 Plot of heeling moments and angles

A progressive plot should be run during the test to ensure that acceptable data is being obtained. See Figure 7. Typically, the abscissa of the plot will be heeling moment (weight (W) times distance (x)) and the ordinate will be the tangent of the heel angle ($\tan\theta$ = deflection of the pendulum divided by the length of the pendulum). This plotted line will not necessarily pass through the origin or any other particular point for no single point is more significant than any other point.

Plotting all of the readings for each of the pendulums during the inclining experiment will highlight any internal or external influences on the test. If (W) (x)/$\tan\theta$ is constant, a line drawn through the plotted points will be straight. If not then, for solid weight transfer, a linear regression analysis is often used to fit the straight line through the points.

The use of a linear regression analysis is not always appropriate for liquid weight transfers, since the action of moving the ballast can result in a significant change to the vessels VCG at each shift thereby resulting in a different GM at each shift. As the slope of the curve is a function of GM it will be noted that the plots of heeling moment against deflection will not lie on a straight line.

In order to eliminate the effects of changes to the GM it is necessary to consider the check plot in terms of righting lever, GZ.

GZ = Righting (heeling) Moment/Displacement and,

GZ = GM$\sin\theta$ (for small angles)

The check GZ plot corrected for changes in VCG is therefore:

$$GZcorr = \text{Heeling Moment/Displacement} \pm GG_1 \sin\theta$$

Where: Heeling Moment is the total moment measured from the start of the test

GG_1 is the change in VCG due to ballast shift and,
= Vertical Moment/Displacement

Vertical Moment is the total change in moment measured from the start of the test.

θ is the angle of heel measured from the start of the test.

Deviations from a straight line are an indication that other moments are acting on the ship during the inclining test. These other moments should be identified, the cause corrected, and the weight movements repeated until a straight line is achieved. Figure 8 illustrates examples of how to detect some of these other moments during the inclining, and a recommended solution for each case. For simplicity, only the average of the readings is shown on the inclining plots.

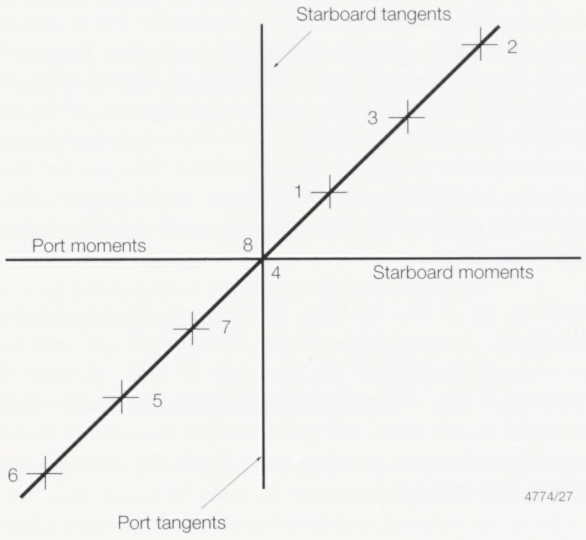


Figure 7 – Progressive heeling moment plot

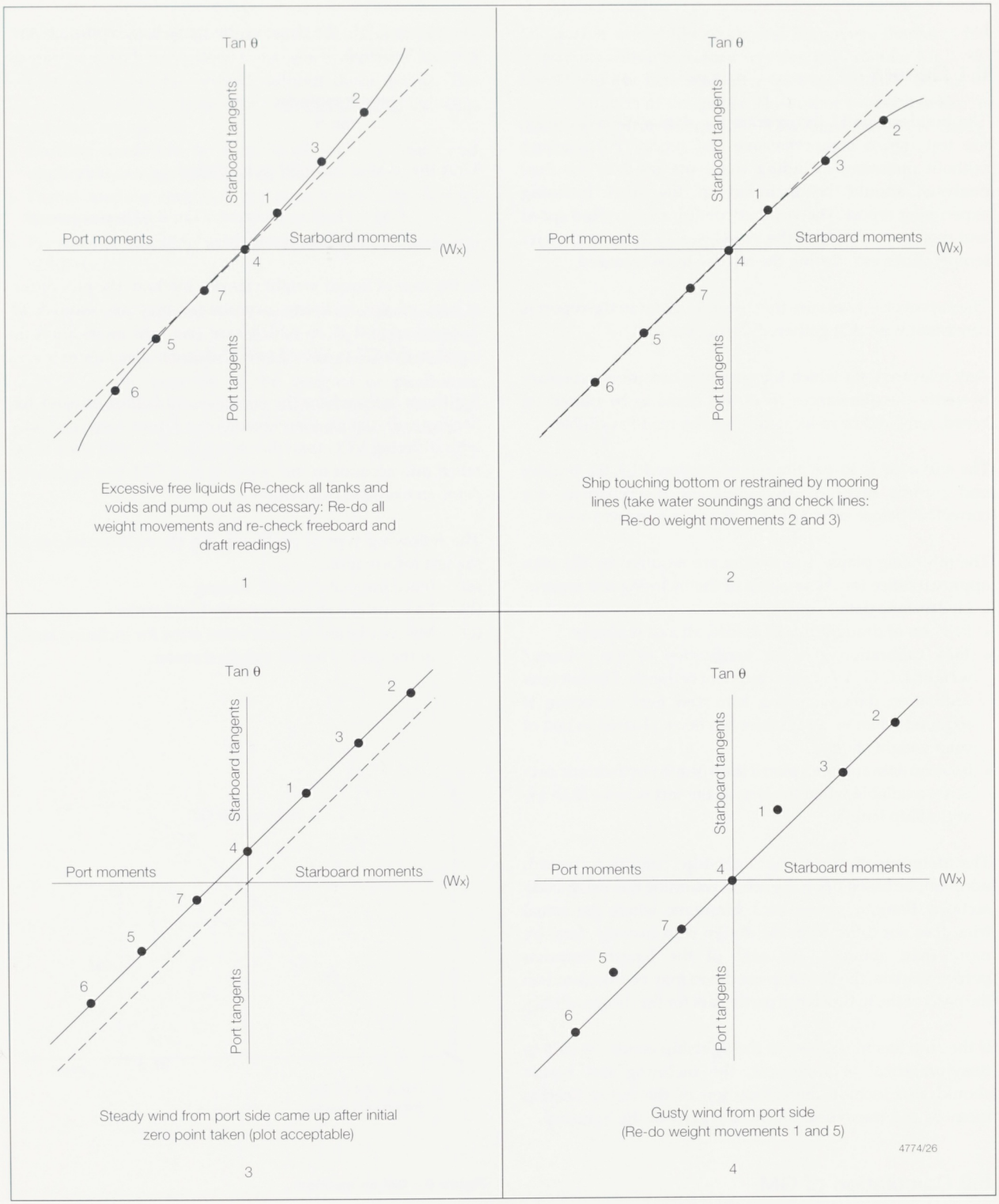


Figure 8 – Heeling moment plots which highlight disturbing moments during a test

6 Test results and test report

6.1 General

The builder should incorporate the data gathered during the test into a comprehensive test report. All readings without omission, including those not used in the final analysis, should be included in the final inclining experiment report. The weather conditions, i.e. wind speed and direction relative to the vessel, sea state, air and water temperatures etc., during the test are to be recorded.

The surveyor is to ensure that the data given in the report is consistent with that gathered during the test.

Any relevant data which the surveyor considers necessary to verify the allowances made for items to be placed on board, removed or re-located, are to be made available.

The surveyor is to vet the report prepared by the builder and inform them of any apparent discrepancies for correction before submission to the plan approval office.

The following plans/information are required by the plan approval office for the analysis of the inclining test report:

- Hydrostatic data
- Position of draught marks at fore, aft and midships
- Tank calibration data for verification of the volume/weight, L.C.G., V.C.G. and moment of inertia. Further tank calibration data including trim and heel correction is required when water transfer has been adopted in lieu of solid weight shifts.
- Bonjean data and lines plan if the trimmed hydrostatic data is not available when the trim at the test is more than 1% of the ship length.

The determination of the lightship condition would, normally, be based upon the actual waterline (i.e. using body sections, Bonjean curves, etc.). However, where the actual trim does not differ from the design trim (usually zero) by more than about 1 per cent of the length between perpendiculars, the lightship condition may be calculated on the basis of the hydrostatics particulars for the designed trim.

If the ship has initial heel at the lightship condition due to unsymmetrical arrangement, the inclining test report should also include the calculation of the initial heeling moment and transverse centre of gravity of the lightship.

6.2 Calculation of GM

The recommended method of calculating the GM from the results of an inclining experiment is as follows:

Use a linear regression analysis to fit a line through the plot of the heeling moments versus the tangent of the heeling angles using the formula:

$$Y = a + bX$$

where: Y = Heeling moment (abscissa)
X = Tangent of the heeling angle, $\tan\theta$ (ordinate)

The value of 'b' , the slope of the trend line, represents the average value of:

$$\frac{\text{heeling moment}}{\tan\theta}$$

Thus the 'GM as inclined' is given by:

$$GM = \text{Heeling moment}/(\text{Tan}\,\theta \times \text{Displacement})$$
$$= b/\text{Displacement}$$

In the case of liquid weight transfer method, the plot of the results of the inclining experiment may be plotted as 'GZcorr against θ' in which case the 'GM as inclined' is equal to the GZ projected to 57.3 degrees. See Figure 9.

For those cases where the use of liquid ballast transfer for heeling will require the movement of liquid between tanks with differing VCG then the change in VCG will need to be taken into account in the calculation of GM. See Appendix A for an example calculation.

The following typical problems can cause inaccuracies in the test information:

(a) Inaccuracy of draught reading
(b) Free surface effects of partly filled tanks
(c) Miscalculation or calculation error for inclining tanks in the case of liquid weight transfer.

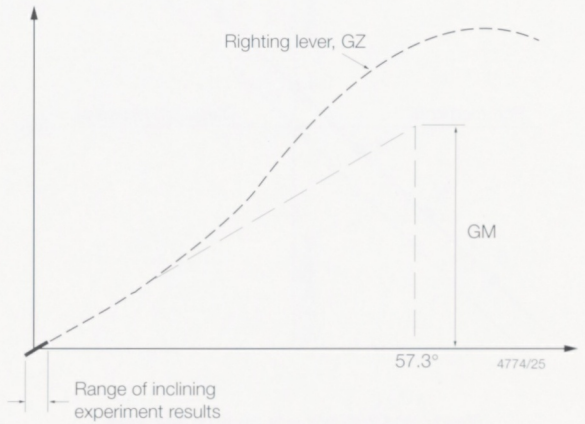


Figure 9 – GM as inclined

7 Conclusion

The lightship parameters of any vessel are an essential basic element of stability calculations since accurate loading conditions cannot be derived without these details. The following items have to be reviewed once the final lightship particulars are agreed:

- Loading conditions for compliance with the intact and applicable damage stability regulations
- Partial loading condition for compliance with SOLAS damage stability
- Provisional stability manual in accordance with the SDSPM.

Past experience highlights the need for absolute accuracy and attention to detail when carrying out inclining experiments on large ships as small errors in measurement, whether in the position of the weights or pendulum readings, can make significant differences in the final results of ships with large GMs in the inclined condition.

8 Acknowledgements

The author would like to express his sincere thanks to his colleagues within Statutory Services, in particular Mr. C.M. Magill and Mr. D.V. Whittaker for their valuable advice in the preparation of this paper. The author would also like to thank Mr. A.N. Stephens, CSD, Yokohama and Mr. N. Sakai, LR Kobe.

References

(1) Australian DOT
Method of performing and reporting upon inclining experiments and lightweight measurement – Marine Order Part 13

(2) UK, DOT
Notes for guidance for carrying out an inclining test

(3) IMO Resolution A.749(18)

(4) Lloyd's Register
Ship Division Survey Procedures Manual

Appendix A – Sample of inclining test report

1 Conditions

Date of test:	January 27, 1995
Place:	No. 1 Dock
Weather and wind:	5 m/s
Temperature of atmosphere:	9.0°C
Temperature of sea water:	10.0°C
Witness class:	Mr. LR
Owner:	Mr. Owners

2 Draught etc.

	Port		*Starboard*		*Mean*
Fore at Draught mark	4.297 m		4.291 m		4.294 m
Midship at draught mark	4.215 m		4.235 m		4.225 m
Aft at draught mark	4.301 m		4.305 m		4.303 m
Apparent trim	4.303	–	4.294	=	0.009 m (by the stern)
Correction of fore draught					0.000 m(1)
Correction of aft draught					0.001 m(1)
Draught at F.P.	4.294	–	0.000	=	4.294 m
Draught at A.P.	4.303	+	0.001	=	4.304 m
Mean of fore and aft draughts	4.299 m				
Deflection (Hogging)	4.225	–	4.299	=	-0.074 m
Correction of deflection	-0.074	x	3/4	=	-0.056 m
Corrected mean draught (d1)	4.299	–	0.056	=	4.243 m
Displacement corresponding to above draught (ρ = 1.025)				=	37,092 kt
Trim	4.304	–	4.294	=	0.010 m (by the stern)
Change of displacement due to trim				=	-4.6 kt(2)
Corresponding displacement (ρ = 1.025)				=	37,087 kt

Corrected displacement for specific gravity :

Specific gravity of sea water

	Port		Stb'd
Fore		1.0220	
Mid	1.0225		1.0225
Aft		1.021	
Mean		1.022	

Actual displacement

37,087 kt x 1.022/1.025 = 36,979 kt

(1) Draught correction at perpendiculars (see Figure 10)
Apparent Trim = (Draught at stern) – (Draught at stem)
Fore correction = -l f x Apparent trim/L
Aft correction = l a x Apparent trim/L

(2) Displacement correction due to trim
= [(Actual trim x 100) x MF/LBP] x T.P.C.
where MF ..... Distance from midship to centre of floatation at draught d1
T.P.C. ... Tonnes per cm immersion at draught d1

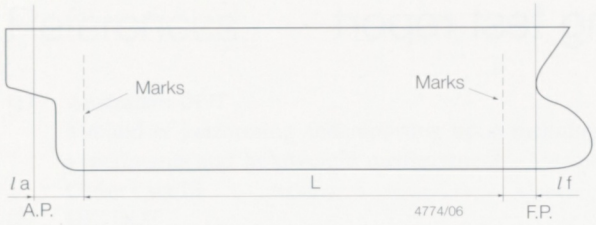


Figure 10 – Draught correction

3 Condition at the test

Displacement	36,979 kt
Trim by stern	0.010 m
Longitudinal centre of buoyancy from midship (MB)	-13.88 m
Transverse Metacentre above base line (TKM)	36.58 m

4 Results of inclining test

4.1 Procedure of shifting ballast water

Shift No. 1	No. 2 TOP S. TK. (P)	→	No. 2 BTM. S. TK. (S)
Shift No. 2	No. 2 TOP S. TK. (P)	→	No. 2 BTM. S. TK. (S)
Shift No. 3	No. 3 T&B S. TK. (S)	→	No. 3 T&B. S. TK. (P)
Shift No. 4	No. 3 T&B S. TK. (S)	→	No. 3 T&B. S. TK. (P)
Shift No. 5	No. 3 T&B S. TK. (S)	→	No. 3 T&B. S. TK. (P)
Shift No. 6	No. 3 T&B S. TK. (S)	→	No. 3 T&B. S. TK. (P)
Shift No. 7	No. 2 TOP S. TK. (P)	→	No. 2 BTM. S. TK. (S)
Shift No. 8	No. 2 TOP S. TK. (P)	→	No. 2 BTM. S. TK. (S)

4.2 Position and Length of Pendulum

Fore: Upper Deck Fore (FR282) Length (L1) = 18.035 m

Aft: Upper Deck Aft (FR 75) Length (L2) = 18.013 m

4.3 Transverse metacentric height (GoM)

GoM = SHIFTING MOMENTS/(DISPLACEMENT x TANGENT θ)

Item				0	1st	2nd	3rd	4th
Direction of shifts					P → S	P → S	S → P	S → P
Reading of pendulum	Fore		mm	546	699	859	710	552
	Aft		mm	542	698	856	704	548
Deviation of	Fore	(s1)	mm	–	153	160	149	158
Pendulum	Aft	(s2)	mm	–	156	158	152	156
Mean tan θ = 1/2(s1/L1 +s2/L2)				–	0.008572	0.008822	0.008350	0.008711
Shifting weight			kt	–	308.20	301.40	287.50	284.80
Shifting moments			kt-m	–	7883.0	8170.0	7722.0	8132.0
Displacement			kt	36,979				
GoM = Shifting Mt./(DISP x tan θ)			m	–	24.87	25.05	25.01	25.25
GoM correction[3]			m	–	-0.02	-0.22	-0.23	-0.42
Corrected GoM			m	–	24.85	24.83	24.78	24.83
Mean GoM			m	24.80				

Item				5th	6th	7th	8th
Direction of shifts				S → P	S → P	P → S	P → S
Reading of pendulum	Fore		mm	398	238	392	553
	Aft		mm	391	228	388	546
Deviation of	Fore	(s1)	mm	154	160	154	161
Pendulum	Aft	(s2)	mm	157	163	160	158
Mean tan θ = 1/2(s1/L1 +s2/L2)				0.008627	0.008960	0.008711	0.008849
Shifting weight			kt	277.20	285.30	300.50	299.00
Shifting moments			kt-m	8065.0	8469.0	8324.0	8495.0
Displacement			kt	36,979			
GoM = Shifting Mt./(DISP x tan θ)			m	25.28	25.56	25.84	25.96
GoM correction[3]			m	-0.61	-0.79	-0.99	-1.18
Corrected GoM			m	24.67	24.77	24.85	24.78
Mean GoM			m	24.80			

(3) Considering the effect of movement downward of centre of gravity by the transfer of ballast water from one tank to another tank and change of free surface moments, GoM in each test cases is converted into GoM relating to the original tank condition as follows;

GoM correction = GoM correction moments/Displacement

ΔFS.MT ΔKG.MT

Shift No. 1 GoM correction = (6547 - 7387)/36979 = -0.02m

Shift No. 2 GoM correction = (6221 - 14299)/36979 = -0.22m

Shift No. 3 GoM correction = (12432 - 20983)/36979 = -0.23m

Shift No. 4 GoM correction = (11837 - 27529)/36979 = -0.42m

Shift No. 5 GoM correction = (11131 - 33524)/36979 = -0.61m

Shift No. 6 GoM correction = (10114 - 39436)/36979 = -0.79m

Shift No. 7 GoM correction = (9505 - 46029)/36979 = -0.99m

Shift No. 8 GoM correction = (8757 - 52238)/36979 = -1.18m

Corrected GoM = GoM + GoM correction

4.3.1 Detailed condition of the inclining tanks

(BEFORE THE SHIFTS)

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.2 TOP S.TK.(P)	1882.0	17.442	32826	22.149	41684	8
No.2 BTM S.TK.(S)	358.4	10.226	3665	0.186	67	35679
TOTAL	2240.4	13.016	29161	18.636	41751	35687

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.3 T&B S.TK.(S)	4681.7	15.960	73456	10.310	48268	0
No.3 T&B S.TK.(P)	368.9	11.697	4315	0.237	87	25737
TOTAL	5050.6	13.690	69141	9.574	48355	25737

(AFTER THE EACH SHIFT)

(Shift No.1) *No.2 TOP S.TK.(P) > No.2 BTM S.TK.(S) (308.2MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.2 TOP S.TK.(P)	1569.2	17.924	28126	21.754	34136	4911
No.2 BTM S.TK.(S)	662.0	10.346	6848	0.345	228	37323
TOTAL			21278		34364	42234

(Shift No.2) *No.2 TOP S.TK.(P) > No.2 BTM S.TK.(S) (301.4MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.2 TOP S.TK.(P)	1264.5	18.284	23120	21.334	26977	3553
No.2 BTM S.TK.(S)	960.1	10.428	10012	0.495	475	38355
TOTAL			13108		27452	41908

(Shift No.3) *No.3 T&B S.TK.(S) > No.3 T&B S.TK.(P) (287.5MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.3 T&B S.TK.(P)	4396.8	15.740	69206	9.415	41396	5015
No.3 T&B S.TK.(S)	658.9	11.818	7787	0.418	276	26933
TOTAL			61419		41671	31948

(Shift No.4) *No.3 T&B S.TK.(S) > No.3 T&B S.TK.(P) (284.8MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.3 T&B S.TK.(P)	4107.3	15.695	64464	8.419	34579	3731
No.3 T&B S.TK.(S)	938.9	11.904	11177	0.582	546	27622
TOTAL			53287		35125	31353

(Shift No.5) *No.3 T&B S.TK.(S) > No.3 T&B S.TK.(P) (277.2MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.3 T&B S.TK.(P)	3831.7	15.603	59786	7.362	28209	2618
No.3 T&B S.TK.(S)	1217.8	11.959	14564	0.756	921	28209
TOTAL			45222		29130	30647

(Shift No.6) *No.3 T&B S.TK.(S) > No.3 T&B S.TK.(P) (285.3MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.3 T&B S.TK.(P)	3544.8	15.453	54778	6.159	21832	1601
No.3 T&B S.TK.(S)	1501.6	12.004	18025	0.923	1386	28029
TOTAL			36753		23218	29630

(Shift No.7) *No.2 TOP S.TK.(P) > No.2 BTM S.TK.(S) (300.5MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.2 TOP S.TK.(P)	961.1	18.701	17974	20.856	20045	2355
No.2 BTM S.TK.(S)	1257.7	10.487	13190	0.647	814	38944
TOTAL			4784		20859	41299

(Shift No.8) *No.2 TOP S.TK.(P) > No.2 BTM S.TK.(S) (299.0MT)*

Tank Name	*WEIGHT (M.T.)*	*CL.G (m)*	*CL.G-MT (M.T.-m)*	*KG (m)*	*KG-MT (M.T.-m)*	*FS-MT (M.T.-m)*
No.2 TOP S.TK.(P)	660.8	19.174	12670	20.306	13418	1344
No.2 BTM S.TK.(S)	1555.4	10.532	16381	0.792	1232	39207
TOTAL			-3711		14650	40561

4.3.2 Shifting moment

SHIFT No.	BEFORE SHIFT (CL. G MOMENT)		AFTER SHIFT (CL. G MOMENT)		SHIFTING MOMENT
1)	29,161	–	21,278	=	7,883
2)	21,278	–	13,108	=	8,170
3)	69,141	–	61,419	=	7,722
4)	61,419	–	53,287	=	8,132
5)	53,287	–	45,222	=	8,065
6)	45,222	–	36,753	=	8,469
7)	13,108	–	4,784	=	8,324
8)	4,784	–	-3,711	=	8,495

4.3.3 Delta KG moment and Delta FS moment

Delta KG MOMENT : BEFORE SHIFT

No. 2 TOP S. TK. (P)	AND No. 2 BTM. S. TK. (S)	KG-MOMENT	41,751
No. 3 T&B S. TK. (S)	AND No. 3 T&B S. TK (P)	KG-MOMENT	48,355
	TOTAL (ORIGINAL) 90,106		

No.	No.2 TOP S.TK.(P) AND No.2 BTM.S.TK.(S)		No.3 T&B S.TK.(S) AND No.3 T&B S.TK.(P)		SHIFT ORIGINAL		DKG-MOMENT (M.T. -m)
1)	(34,364	+	48,355)	–	90,106	=	-7,387
2)	(27,452	+	48,355)	–	90,106	=	-14,299
3)	(27,452	+	41,671)	–	90,106	=	-20,983
4)	(27,452	+	35,125)	–	90,106	=	-27,529
5)	(27,452	+	29,130)	–	90,106	=	-33,524
6)	(27,452	+	23,218)	–	90,106	=	-39,436
7)	(20,859	+	23,218)	–	90,106	=	-46,029
8)	(14,650	+	23,218)	–	90,106	=	-52,238

Delta FS MOMENT : BEFORE SHIFT

No. 2 TOP S. TK. (P)	AND No. 2 BTM. S. TK. (S)	FS-MOMENT	35,687
No. 3 T&B S. TK. (S)	AND No. 3 T&B S. TK (P)	FS-MOMENT	25,737
	TOTAL (ORIGINAL) 61,424		

No.	No.2 TOP S.TK.(P) AND No.2 BTM.S.TK.(S)		No.3 T&B S.TK.(S) AND No.3 T&B S.TK.(P)		ORIGINAL DFS.MT		DFS-MOMENT (M.T. -m)
1)	(42,234	+	25,737)	–	61,424	=	6,547
2)	(41,908	+	25,737)	–	61,424	=	6,221
3)	(41,908	+	31,948)	–	61,424	=	12,432
4)	(41,908	+	31,353)	–	61,424	=	11,837
5)	(41,908	+	30,647)	–	61,424	=	11,131
6)	(41,908	+	29,630)	–	61,424	=	10,114
7)	(41,299	+	29,630)	–	61,424	=	9,505
8)	(40,551	+	29,630)	–	61,424	=	8,757

4.3.4 GoM correction moment

SHIFT No.	Delta FS-MOMENT (M.T. -m)		Delta KG-MOMENT (M.T. -m)		GoM CORR. MT. (M.T. -m)
1)	6,547	–	7,387	=	-840
2)	6,221	–	14,299	=	-8,078
3)	12,432	–	20,983	=	-8,551
4)	11,837	–	27,529	=	-15,692
50	11,131	–	33,524	=	-22,393
6)	10,114	–	39,436	=	-29,322
7)	9,505	–	46,029	=	-36,524
8)	8,757	–	52,238	=	-43,481

4.4 Correction for Free Surface (GoG)

Compartment	Density of liquid	Moment of inertia free surface (M*4)	Initial free surface moment (M.T -M)
No. 1 bottom side tank (P)	SW 1.0200	249	254
No. 1 bottom side tank (S)	SW 1.0200	80	82
No. 2 top side tank (P)	SW 1.0200	8	8
No. 2 bottom side tank (S)	SW 1.0200	34,979	35,679
No. 3 top and bottom side tank (P)	SW 1.0200	25,233	25,737
Fresh water tank	FW 1.000	132	132
Drink water tank	FW 1.000	134	134
Deep F.O. tank (P)	FO 0.9761	130	127
Diesel oil tank (S)	DO 0.8592	43	37
Lub. oil sump tank	LO 0.8940	16	14
Bilge tank	OT 1.000	18	18
Total			62,222

Correction for free surface:
GoG = Initial F.S. MOMENT (M.T. – M)/Displacement (M.T.) = 62,222/36,979 = 1.68 m

5 Centre of gravity at the test

Transverse Metacentre above B.L. (TKM) .....36.58 m
Metacentre Height as Measured (GoM) .....24.80 m
Correction due to Free Surface (GoG) .....1.68 m
Metacentre Height after Correction
for Free Surface (GM = GoM + GoG) .....26.48 m
Centre of Gravity above Base Line (KG = TKM – GM) .....10.10 m
Centre of Gravity from Midship
(MID G = MB + Trim x M.T.C.x 100 /Displacement).....-13.84 m

6 Light ship condition

ITEM	WEIGHT	CENTRE OF GRAVITY			
		FROM MIDSHIPS +: AFT, -: FORE		ABOVE BASE LINE	
SHIP WEIGHT AT THE DRAUGHT MEASUREMENT	36,978.85	-13.84	-511,787	10.10	373,486
WEIGHT TO TAKEN OUT	-17,462.87		+712,722		-127,797
WEIGHT TO BE ADDED	+31.10		+3,110		+492
LIGHTSHIP	19,547.08	+10.44	+204,045	12.59	246,181
(SAY)	19,547 M.T.				

Appendix B – Lightship data

1 Introduction

This appendix shows the lightship particulars together with the principal dimensions of the ships built in Japan, Korea and China since 1980.

The data of the following ship types are contained in this appendix:

Bulk carrier
Ore carrier
Container ship
General cargo ship
Oil tanker
Chemical tanker
LPG/LNG carrier
Vehicle carrier
Refrigerated cargo
Passenger ship
Tug boat
Supply boat
Tank barge
Deck cargo ship

The ships used in the data range from a 1,800 PS tug boat to a 300,000 dwt ore/oil carrier.

2 Data presentation

2.1 General

It is well known that even the lightship particulars of sister vessels can vary, therefore, in order to find out the parameters which affect the lightship particulars, the gathered data has been plotted against the value of 'Length x Breadth x Depth' (LxBxD or LBD).

2.2 Diagram of data

2.2.1 Lightweight

The diagrams for the following ship types have been prepared:

All ships	(Figure 11)
Bulk carrier	(Figure 12)
Oil tanker	(Figure 13)
Chemical tanker	(Figure 14)
Container ship	(Figure 15)
General cargo	(Figure 16)
Tug and Supply boat	(Figure 17)
Vehicle carrier	(Figure 18)
Refrigerated cargo ship	(Figure 19)
LPG and LNG carrier	(Figure 20)
Other ships	(Figure 21)

2.2.2 Longitudinal centre of gravity (L.C.G.)

The ratio (L.C.G./Lbp) values have been plotted against Lbp. (See Figure 22)

2.2.3 Vertical centre of gravity (V.C.G.)

The ratio (V.C.G./Depth) values have been plotted against Lbp. (See Figure 23)

2.2.4 Lightweight of Panamax bulk carrier

As the lightship weight consists of hull weight and equipment weight, a large governing factor in the hull weight must be Rule scantlings. Therefore 'Lightweight/LBD' against 'Date of midship section approved' has also been prepared as Figure 24.

It is considered that the effects of the Rule scantlings have been clearly indicated in this data.

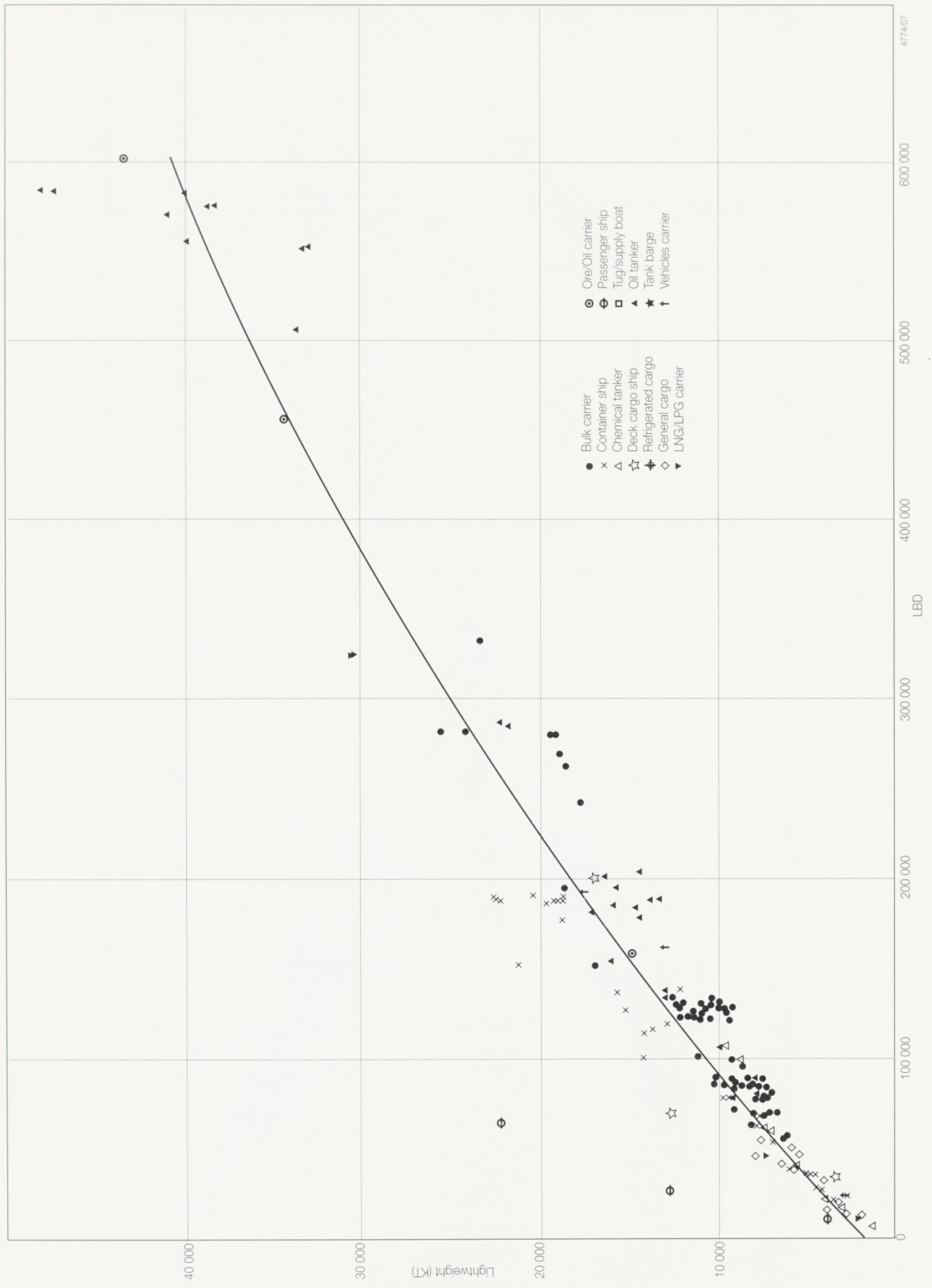


Figure 11 – All Ships

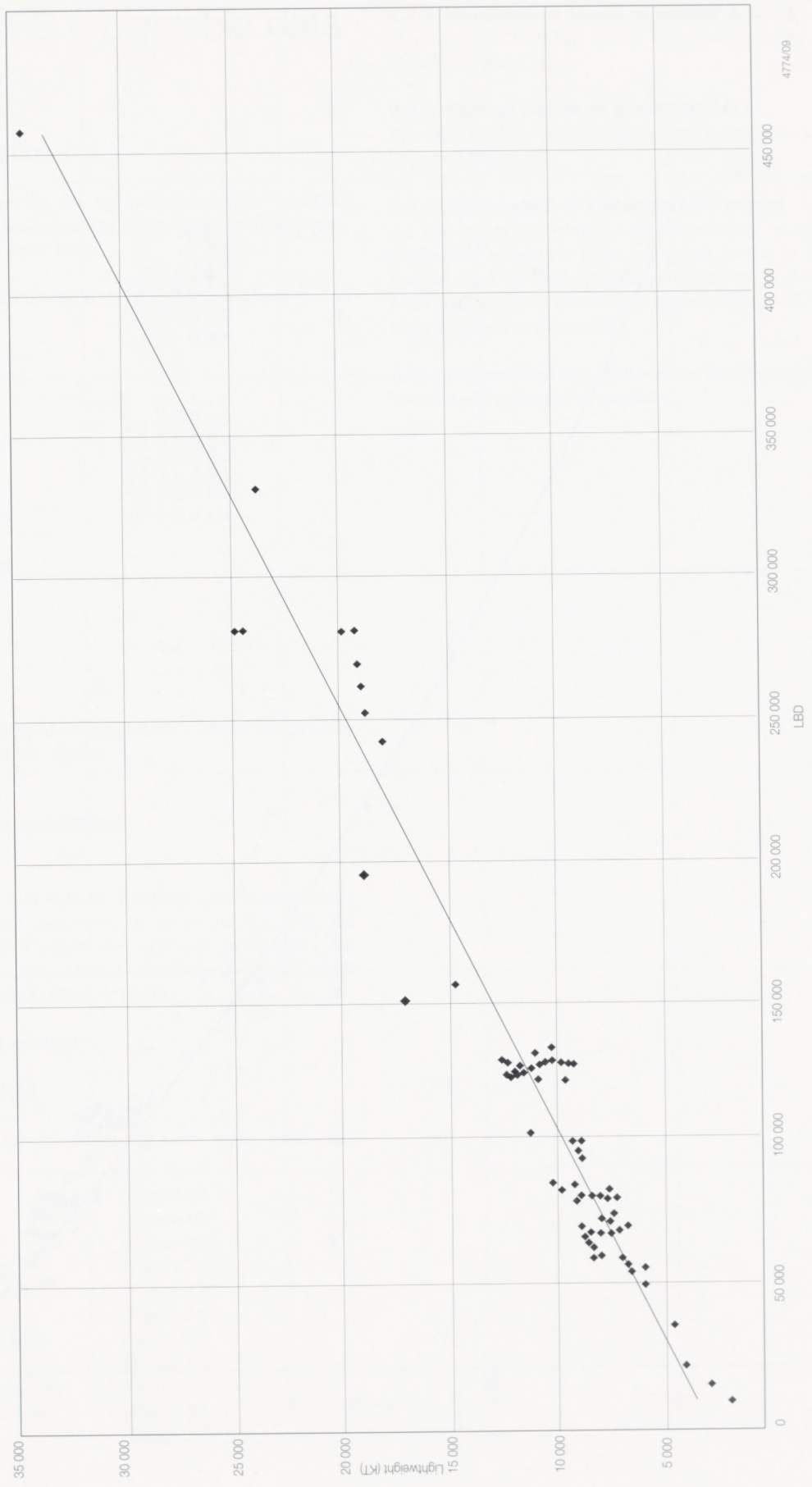


Figure 12 – Bulk Carrier

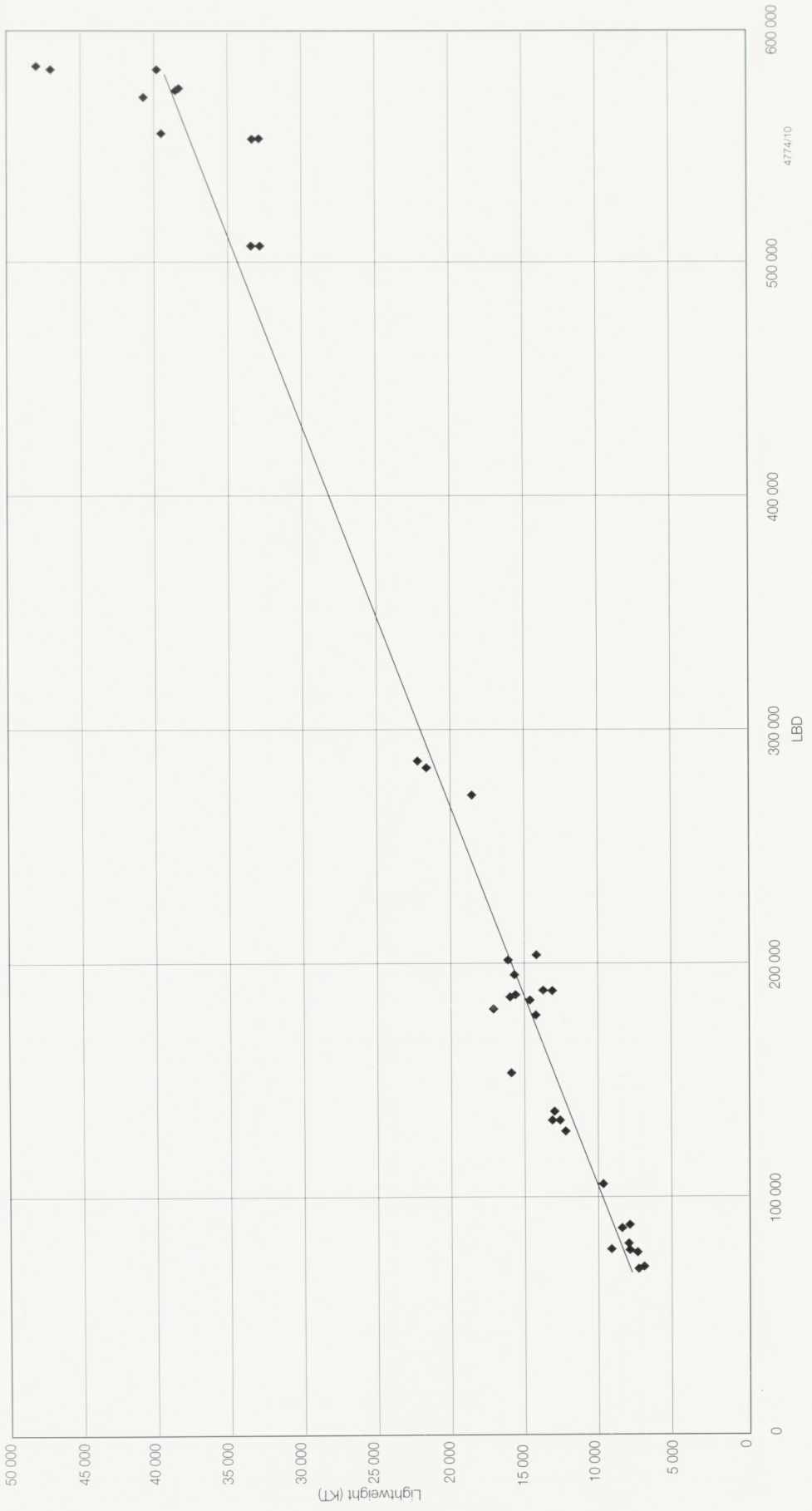


Figure 13 – Oil Tanker

Figure 14 – Chemical Tanker

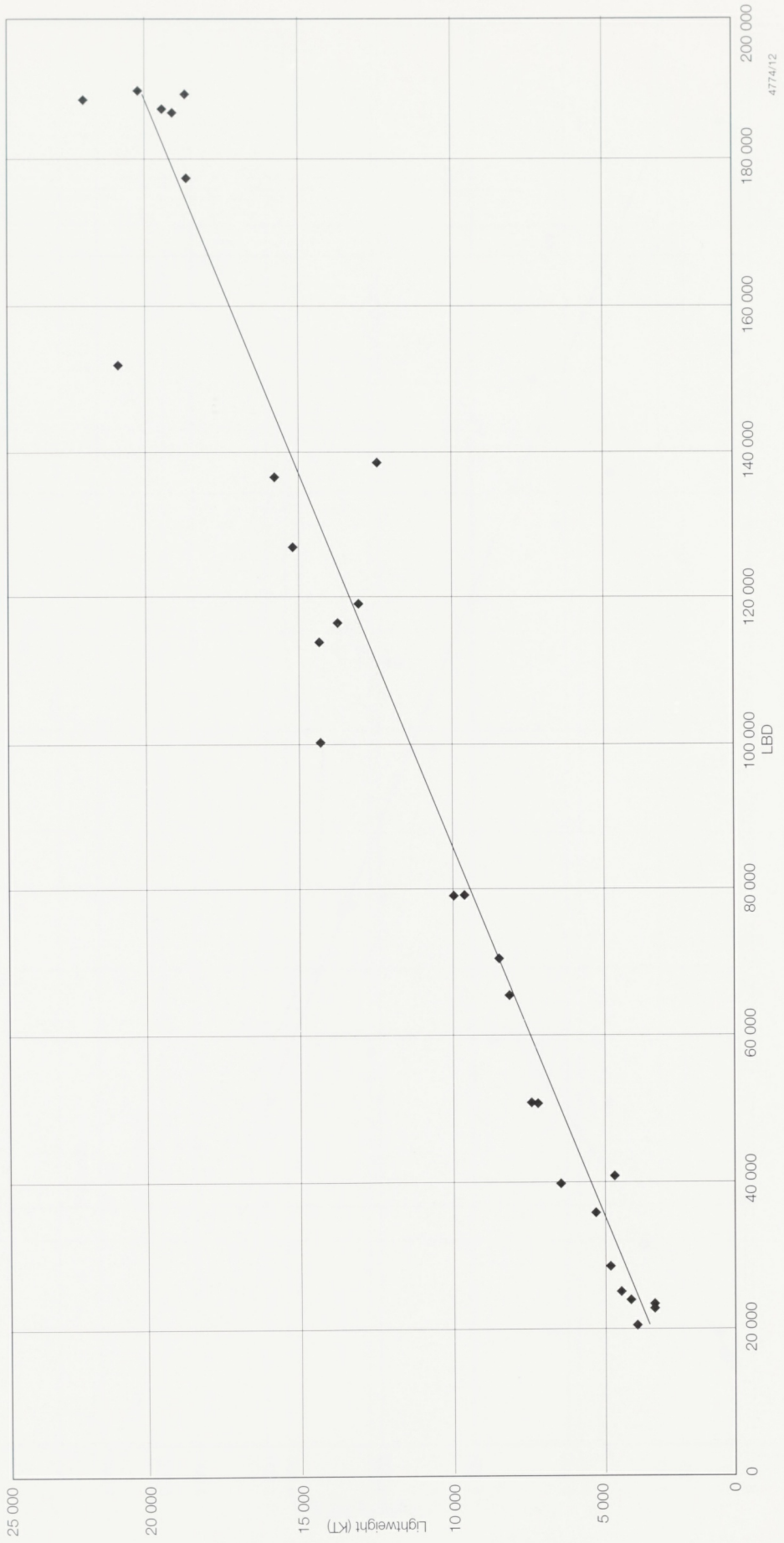


Figure 15 – Container Ship

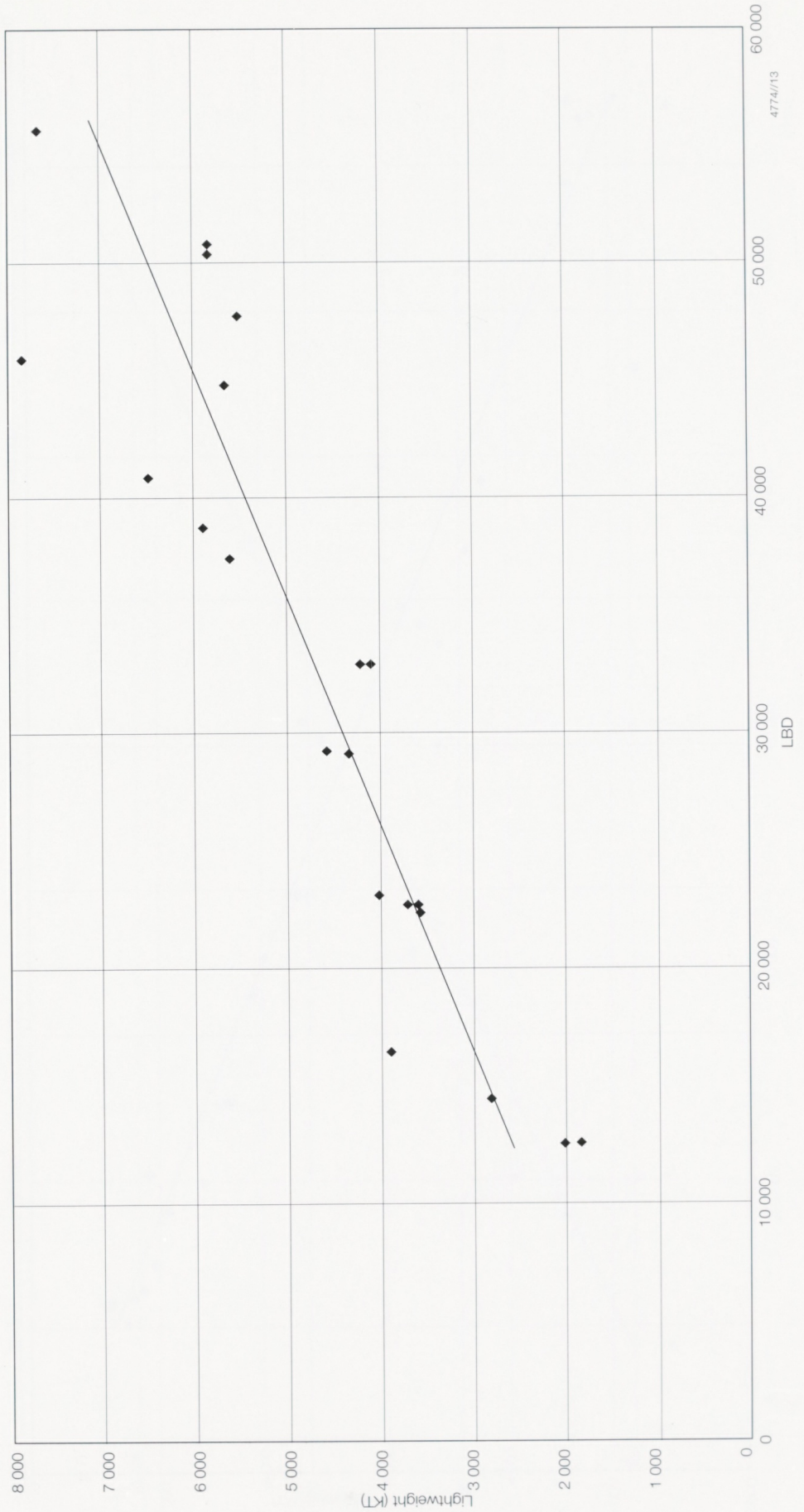


Figure 16 – General Cargo

Figure 17 – Tug and Supply Boat

Figure 18 – Vehicle Carrier

Figure 19 – Refrigerated Cargo Ship



Figure 20 – LNG and LPG Carrier

Figure 21 – Other Ship Types



Figure 22 – Longitudinal Centre of Gravity (LCG)

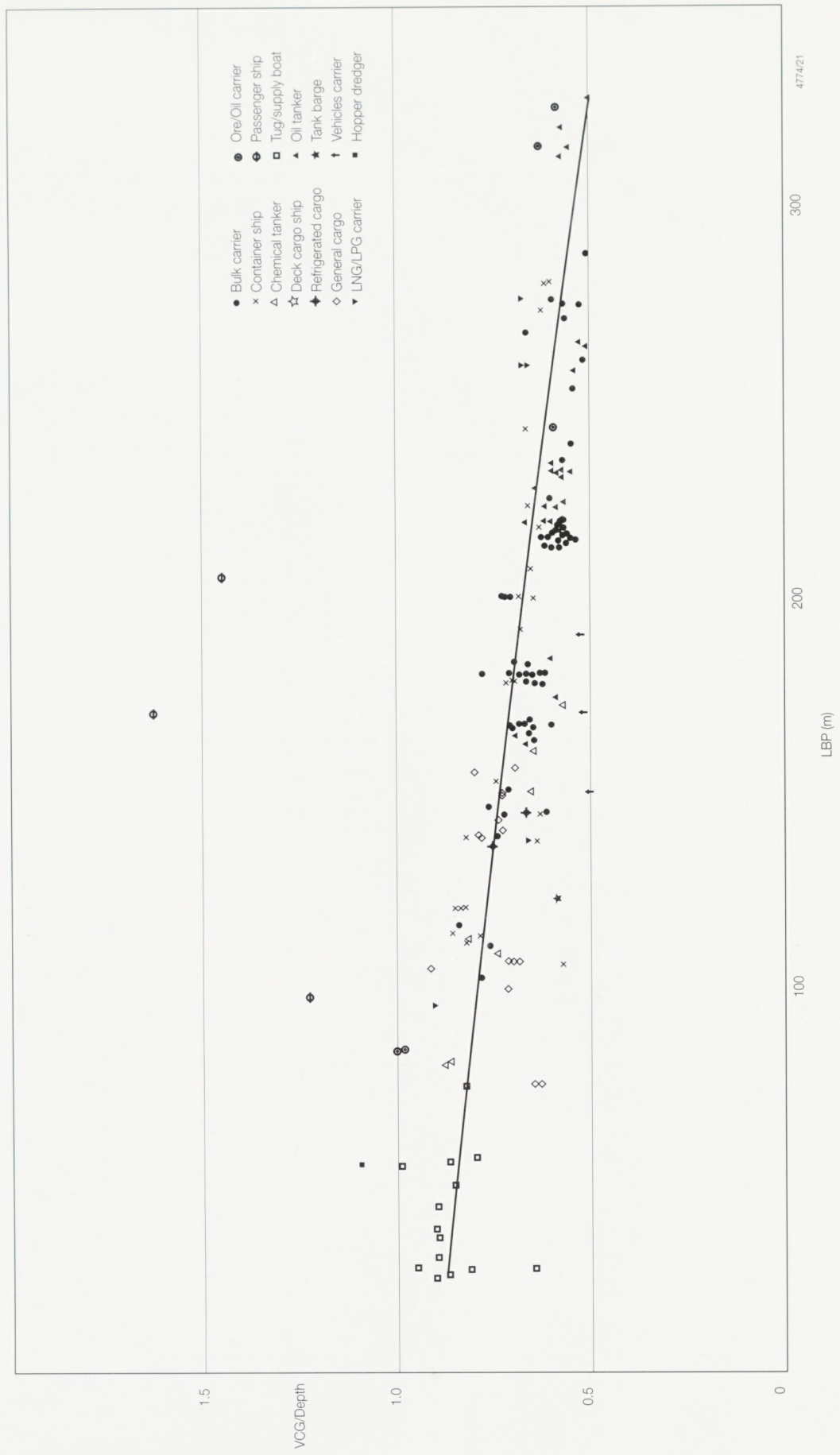


Figure 23 – Vertical Centre of Gravity (VCG)

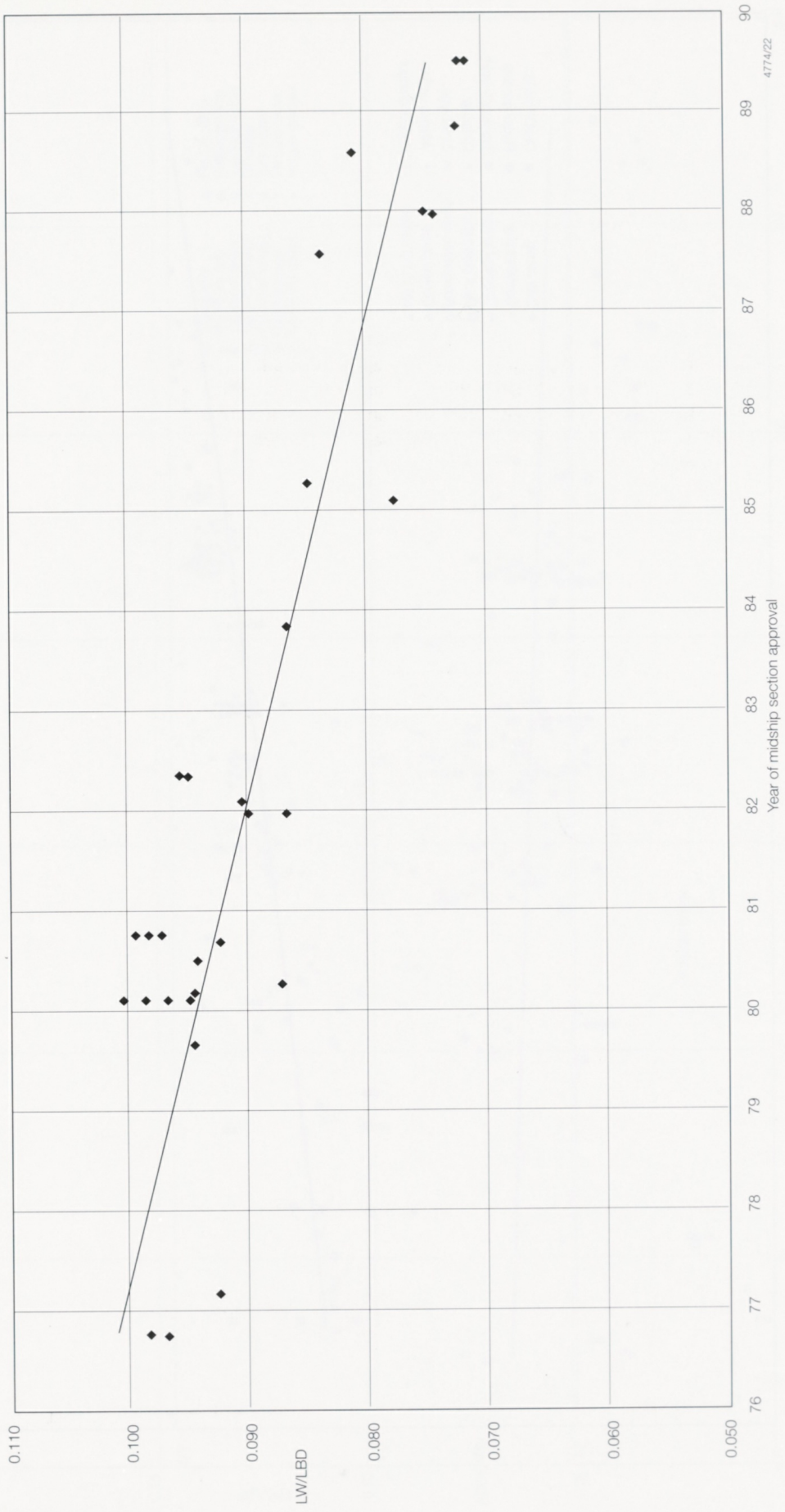


Figure 24 – Lightweight of Panamax Bulk Carrier

LR *Technical Association*

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by P. K. W. Lam, P. F. Moysey and O. C. Whiteaker

Lloyd's Register

Paper No **3**
Session 1996–1997

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Written contributions to the discussion of this paper are invited from members of the Lloyd's Register Technical Association. To ensure inclusion in the discussion paper, the contributions should be received by the Hon. Secretary in London not later than 28th February 1997.

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LR *Technical Association*

Discussion on the Paper

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The European Pressure Equipment Directive (97/23/EC)

by P.K.W. Lam, P.F. Moysey and O.C. Whiteaker

INTRODUCTION

Subsequent to the publication of LRTA Paper No. 3, the European Parliament, European Commission and the Council of Ministers have been involved in intense discussion regarding the fourteen amendments to the 'Common Position' text proposed by the Parliament at the Directive's second reading. An agreement has now been reached and an amended Directive has been passed by the European Parliament and adopted by the European Commission, as of 29th May, 1997. The Pressure Equipment Directive has been given the number 97/23/EC and the final text has now been published in the Official Journal of the European Communities (ref. O.J. No. L 181, dated 9th July, 1997). The date for the Directive entering into force is now fixed at 29th November, 1999, becoming mandatory from 30th May, 2002. During this transitional period, manufacturers may either comply with the Directive and affix the 'CE' marking, or comply with the existing requirements of the country in which the pressure equipment is being placed on the market.

The majority of the amendments were merely to clarify the text. The main area of negotiation centred around Amendment 8, which related to the quality assurance modules. The following is a summary of this amendment and its affect, and should be read in conjunction with, and form part of, the LRTA Paper.

> For the quality assurance modules (D, D1, E, E1, H and H1) the common position text requires the Notified Body to carry out periodic audits to ensure that the quality system is being correctly applied. In addition, the Notified Body may make unexpected visits during which it may (must for module H1) carry out or witness the final assessment testing to verify that the quality system is functioning correctly. The amended text will now require the Notified Body to witness or carry out the final assessment during unexpected visits for Category III and IV pressure vessels containing gases or Group 1 liquids, and steam generating or otherwise heated equipment with a risk of overheating. There should also be two such visits during the first year of manufacture. Furthermore, 'one off' items of steam generating or otherwise heated pressure equipment with a risk of overheating, which fall into Category III and are designed and manufactured under Module H, must have the final assessment carried out or witnessed by a Notified Body.

DISCUSSION

From: Mr R. Porter

With reference to products that have been available on the market for a number of years and have never given any indication of being dangerous, does it follow that manufacturers of such products will have to re-design when the Directive comes into force?

To: Mr R. Porter

It must be remembered that the Directive has been negotiated by representatives of all European Member States, and lays down minimum safety requirements based on existing practice throughout Europe. The Essential Safety Requirements are expressed in general terms, i.e. 'materials must be suitable, joint coefficients must be adequate'. Therefore, it is unlikely that existing equipment will fail to satisfy the requirements of the Directive. However, the manufacturer will have to draw up a technical file and be able to demonstrate, to a Notified Body if required, that his design and method of manufacture complies with the Directive. Part of this demonstration can include the previous safety record of the equipment in service.

Where equipment is of an age such that detailed designs no longer exist, the Directive does allow for the design to be proven by experimental means, provided that the product of pressure and volume (PS.V) for vessels is below 6000 bar litres, or the product of pressure and nominal diameter (PS.DN) is less than 3000 bar.

From: Mr J.L. Buxton

The routes through to certification seem quite complicated. Is all this really going to work and are all Member States going to apply the same uniform standards in the application of the Directive? What measures are in place to ensure that standards will be properly applied?

I like the idea of unannounced visits to manufacturers. This seems to be a licence to print money. If we are a bit slack one day we can always make an unannounced visit and charge for it!

On a more serious note, would the Authors like to comment on the likely pricing structure? Are we going to budget for a certain number of visits in a given timescale, or would we charge on an 'as and when' basis, which could prove burdensome for the manufacturer?

To: Mr J.L. Buxton

The system of conformity assessment modules to demonstrate compliance with the Directive has been used for several years in other EC Directives and has been shown to work. With regard to Member States applying uniform standards, it should be recognised that Notified Bodies are appointed against the same criteria which are given in Annex IV of the Directive. In addition, a Standing Committee will be set up by the Commission, which will be composed of representatives appointed by the Member States. This will allow for an exchange of information between Notified Bodies etc. to enable a uniform interpretation of the Directive.

It should also be noted that Member States are legally obliged to give free movement of goods that carry the 'CE' marking, and any objection they wish to raise can only be on the grounds of safety and must be relayed to the Commission for investigation.

With regard to unannounced visits, they fall into two categories; surveillance visits by a Notified Body under Modules A1 and C1, and visits to verify the correct operation of a quality system under modules D, D1, E, E1, H and H1. For the 'direct inspection' surveillance visits (A1 and C1) the Directive does not stipulate a frequency, however, based upon experience from the Simple Pressure Vessels Directive (87/404/EEC), a frequency of once or twice a year depending on the rate of production would appear to be reasonable.

The quality assurance modules state that the frequency of unexpected visits should be based on a visit control system operated by the Notified Body. This should take into consideration the category of the equipment, the results of previous visits, corrective actions issued, conditions linked to the approval of the quality system and any changes in the quality system. The recently agreed amendments also require that for certain types of equipment, two visits should be made in the first year of manufacture. Unexpected visits are in addition to periodic audits of the quality system.

With regard to the pricing structure, it should be noted that there is no requirement in the Pressure Equipment Directive for the same Notified Body to be used throughout the design and production phases, and obviously Notified Bodies may be competing against each other for business. It is likely, that contracts for surveillance visits would be for a set number of visits within a certain length of time, although the actual timing of visits would be unspecified.

From: Mr S.M. Ioannou

I would like to thank the Authors for a very interesting and informative paper and the LR Technical Association for organising this event.

There are three parts to my question:-

(i) Firstly, during the manufacturing stages, would there be more emphasis on quality assurance than the physical inspection of pressure equipment?

(ii) Secondly, will the Directive increase the volume of quality assurance with which the manufacturer normally gets involved, i.e. the extra documentation required to be produced by the manufacturer (quality and technical documentation/records) in order to satisfy the general and specific requirements of the Directive?

(iii) Finally, if the conformity assessment procedures involve specific auditing of the quality system requirements which in turn control the technical documentation, how would these events affect the cost of the manufactured pressure equipment and most importantly the safety of the equipment in relation to what exists at the moment, i.e. quality assurance systems combined with physical inspection and test during the manufacturing stages?

To: Mr S.M. Ioannou

(i) The conformity assessment modules available to the manufacturer to demonstrate compliance with the Directive are self certification, product certification and quality management systems, or a combination of product and quality management certification. Thus, there is no particular emphasis placed on quality assurance rather than physical inspection.

(ii) The Directive requires manufacturers to assemble a technical file containing all relevant information regarding the pressure equipment to demonstrate, to a Notified Body or competent National Authority if necessary, that the equipment meets the Directive's Essential Safety Requirements. Such a file would include drawings, calculations, test results, material specifications and certificates, manufacturing schedules, weld procedure and welder qualifications, etc.

In practice, most diligent manufacturers will maintain such documentation to meet current requirements, although possibly not as a formal package. However, the Directive does not require the technical file to be retained as a formal hard copy, only that manufacturers be able to produce the information when required.

(iii) The only additional cost requirement that the Directive may place on the manufacturer is the requirement to compile a technical document which demonstrates how he has met the Directive's

Essential Safety Requirements. A study has been carried out by the UK Department of Trade and Industry which has concluded that the overall average cost to manufacturers in the UK would be about 1%.

As regards the safety of pressure equipment manufactured under a quality assurance system, the Directive requires sufficient auditing of the system, such that the system is re-appraised every three years, and gives Notified Bodies the power to pay unexpected visits during which it may carry out or witness the final assessment, such that an acceptable level of safety should be assured. Indeed, the revised text of the Directive will require the Notified Body to witness the final assessment for certain types of pressure equipment during the first year of manufacture.

From: Mr R.J. Parry

With the emergence of the European Standard to which the Directive gives rise, will codes such as BS 5500, Stoomwezen and AD Merkblatt disappear?

May I also invite the Authors to comment on the affect upon non-European exporters from, say, the "ASME Area".

To: Mr R.J. Parry

It is a requirement that when a harmonised European Standard (EN) is published all conflicting European National standards are withdrawn. In the case of unfired pressure vessels, it is unfortunate that BS 5500 is one of the current National Standards in Europe to be withdrawn.

AD Merkblatt, CODAP etc. are industry Codes of Practice rather than National Standards and as such do not have to be withdrawn. At present, there are suggestions that some other body should take over BS 5500, such that it becomes a Code of Practice rather than a National Standard, thus allowing it to be retained.

In all cases, the requirement is to satisfy the Essential Safety Requirements of the Directive. Codes of Practice and non-European standards such as ASME are a means that a manufacturer can use to demonstrate compliance with the Directive. However, presumption of conformity will only be given to equipment that is designed and built in accordance with a harmonised EN standard.

From: Mr G.G. Ferrier

The Authors are to be congratulated on this Paper which is on a topic of great importance for manufacturers and the LR Group, both having an interest in gaining a greater freedom of operation within Europe for pressure equipment.

Even prior to ratification, the subject matter raises many thought provoking questions. I would be grateful if the Authors could give further information on the following:-

(i) The Directive requires verification that the lifetime service conditions for pressure equipment can be achieved. Who is responsible for determining this period and what factors would be required to be taken into consideration whilst determining it, bearing in mind the variety of materials and fluids which may be used in a system?

(ii) The Directive states that the materials used in the manufacture of pressure equipment must have suitable properties for its intended use. Who takes responsibility when the purchaser, for commercial reasons, will not divulge the operating fluid specifications?

To: Mr G.G. Ferrier

(i) The Essential Safety Requirements state that the design of pressure equipment must consider all loadings appropriate to the intended use, and for all reasonably foreseeable conditions. They go on to state that the design should consider all possible combinations of loadings, and the possibility of their simultaneous occurrence, as well as corrosion, erosion and other forms of chemical attack. The material properties to be considered as part of the design calculations should include fatigue data where relevant.

Invariably, for individually designed items of pressure equipment, the required lifetime will be specified by the customer, with the designer and manufacturer being responsible for achieving a design that meets the requirement. The manufacturer will also be responsible for compiling the necessary technical documentation to the satisfaction of a Notified Body, if required by the selected conformity assessment route. This will demonstrate that the requirements of the Directive have been satisfied. However, for 'off the shelf' items, the manufacturer will have to include statements in the accompanying instructions regarding the intended life of the item and any necessary maintenance and inspections required to ensure its safety in operation.

(ii) Where a purchaser will not divulge the specification of the operating fluid for commercial reasons, the manufacturer must obtain from him written statements that the selected material is suitable. He will also need confirmation of the appropriate group for the fluid; this will allow him to establish the category and hence the conformity assessment module(s) available. If a Notified Body is required to review the technical file, it may have to enter into confidential consultation with the purchaser to verify that the material is suitable. Alternatively, a statement can be included in the EC Type Examination Certificate that the material has been accepted without knowledge of the working fluid.

From: Mr A.E. McLaughlin

If a manufacturer is given a design by a customer and asked to manufacture to a given specification, who is responsible for obtaining type examination and product approval?

To: Mr A.E. McLaughlin

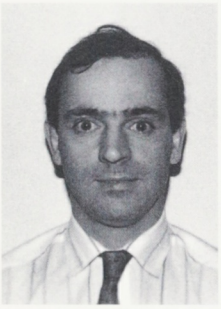
From a legal point of view, the person whose name appears on the data plate (the manufacturer) is responsible for complying with the requirements of the Directive, as it is he who will issue and sign the 'Declaration of Conformity.' In practice there will have to be some form of contractual arrangement between the parties involved, as each will require some information from the other to compile the technical documentation. For instance, the manufacturer would require design data and calculations etc. to compile the file, whereas the designer would require details such as weld procedures and approvals, and manufacturing procedures.

The European Pressure Equipment Directive

by P. K. W. Lam, P. F. Moysey and O. C. Whiteaker



Paul Lam completed a marine-engine fitter apprenticeship with Hong Kong United Dockyards in 1974, then worked as an Engine Draughtsman for two years. In 1978, he obtained his B.Sc. with First Class Honours in Mechanical Engineering from Strathclyde University, and subsequently, by part-time studies, obtained his M.Sc. from Cranfield University in 1980 and a M.B.A. from Strathclyde University in 1989. He joined British Hydromechanics Research Association, Bedford in 1978 where he carried out research in pipeline technology. In 1980, he moved to Foster Wheeler Power Product Ltd., London, where he was involved in water-tube boiler design, project management and design verification of pressure equipment. After a short period with LR in Pressure Plant Department in 1989, he joined M.W. Kellogg in London and Houston, and later moved to Aker Engineering, Norway in 1991 where he was involved in consultancy and design verification of pressure equipment for both onshore and offshore projects. In 1994, he re-joined LR as an Engineer Surveyor in the Pressure Plant Department and was promoted to Senior Surveyor in 1996. He is a European Engineer, Chartered Engineer, Fellow of the Institution of Mechanical Engineers and Fellow of the Institute of Marine Engineers.



Peter Moysey graduated from Imperial College, London in mechanical engineering in 1980 and joined the National Nuclear Corporation. After a two year graduate apprenticeship he worked on the design of the advanced gas cooled reactor cores for Heysham power station, followed by three years as a site engineer overseeing its construction. After returning to the design office he worked on a refurbishment project for some of the older power stations, and then for three years as a design consultant to Nuclear Electric for the reactor building containment liner for Sizewell B power station. This was followed by work as a project engineer on defence related projects and at the Dounreay Nuclear Power Establishment. Mr Moysey joined LR's Type Approval Department in 1995 working on mechanical components and the EC Simple Pressure Vessel Directive. He is currently lead surveyor for the proposed EC Pressure Equipment Directive working towards LR's appointment as a Notified Body.



Clive Whiteaker joined the Reardon Smith Line as an Engineer Cadet progressing to become a Second Engineer Officer. After obtaining a Chief Engineers Certificate he left to spend one year with W H Allen Sons & Co Limited as a Technical Author before spending four years at University College, Cardiff and the Glamorgan Polytechnic. This was followed by a period as a Mechanical Engineer at the UK AEA Calder Hall Nuclear Power Station before joining Lloyd's Register at the Baglan Bay Site in November 1970. Mr Whiteaker gained twenty five years of varied experience in LR in the Marine, Offshore and Industrial fields including site duties in the UK, Iraq, Japan and New Zealand. Contract and co-ordinating engineering in Japan and the UK in primary energy and Nuclear Power fields followed; he was heavily involved in the early years of the Sizewell B contract. Following promoted to Principal Surveyor in charge of Industrial Division's Power Department in 1985 Mr Whiteaker subsequently headed the Division's Power, Business, Marketing and Technical Services departments, the latter involving managing LR Insurance, Inc. World Wide ASME Inspection Services. He transferred to his present Corporate role as EU Liaison Officer in November 1994 where he is responsible for co-ordinating information gathering, utilization and dissemination within the LR Group together with developing LR's opinion forming stance within National and EU organizations for the furtherance of LR's tactical and strategic aims.

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Synopsis

The proposed Pressure Equipment Directive derives from the European Community's (EC) programme for the elimination of technical barriers to trade. Its purpose is to harmonize national laws in relation to the design, manufacture and conformity assessment of pressure equipment and assemblies subject to an internal pressure greater than 0.5 bar gauge (barg). This Paper describes the objectives, content and scope of the proposed Directive with a series of appendices providing details of technical documentation requirements and a case study for future reference.

1 Introduction

The proposed Pressure Equipment Directive is one of the last major measures set out in the single market programme which remains to be agreed. Harmonization in this technically and legally complex sector has been difficult with the result that this proposal has been under discussion since 1989.

Although highly technical, the proposal is most important for the internal market, since it covers a huge range of industrial products in a sector in which considerable trade barriers still exist. In accordance with Article 100a of the Treaty of Rome, the proposal requires the equipment concerned to meet high safety standards if it is to be allowed freedom of movement within the Community. The hazards covered are mainly those from the stored energy and the fluid contained.

At present the national legislation in Member States varies greatly with the UK laws, for example, being less prescriptive than certain other European Union (EU) Member States such as Germany. The objective, therefore, has been to secure agreement to a directive which will remove barriers to trade whilst allowing manufacturers to operate, as far as possible, as efficiently as before. It has been estimated that, in the case of the UK, this new Directive will add one percent to manufacturing costs.

1.1 Outline

Since the Directive has been drafted to the principles set out in the "New Approach to Technical Harmonization and Standardization" of 1985 it has the following characteristics:

- a wide product scope;
- essential safety requirements;
- means of assessing conformity leading to CE marking.

1.2 Scope

The scope of the Directive is discussed in detail later in this Paper but briefly, the proposal covers the design, manufacture and conformity assessment of pressure equipment and assemblies subject to an internal pressure greater than 0.5 barg. Assemblies have been included since most pressure equipment (such as boilers) consists of assemblies of discrete component parts and normally the manufacturer of such an assembly intends it to be placed on the market and put into service as such rather than in its unassembled constituent parts. The proposal, therefore, concerns the manufacture of items such as shell and watertube boilers, heat exchangers, pressure vessels, pressurized storage containers, industrial pipework and associated accessories.

There are a number of specific exclusions, such as equipment falling within the scope of other directives (simple pressure vessels, aerosols and parts for vehicles), equip-

ment for the transport of dangerous substances (transportable gas containers) and equipment for which pressure hazards are low and adequately covered by other directives (machinery directive, low voltage directive and medical devices directive).

1.3 Essential Safety Requirements

Equipment above certain pressure/volume thresholds set out in the Directive will need to meet requirements for the design, manufacture and testing of pressure equipment which are considered to be essential for safety reasons. Equipment manufactured to harmonized European standards, presently being developed in support of the Directive, will be presumed to comply with the applicable essential safety requirements. Equipment below the thresholds will be required simply to be manufactured according to "sound engineering practice".

1.4 Conformity Assessment

To ensure compliance with the essential requirements, equipment will need to be subjected to conformity assessment procedures based on the EC Modules Decision 93/465/EEC of July 1993. For this purpose the Directive divides pressure equipment into four major categories on the basis of two fundamental hazards – the degree of hazard from failure of the equipment and the degree of hazard from the fluid contained. The degree of danger from failure is related to the stored energy that would be released and is expressed by the product of the pressure of the fluid and the volume of the equipment. The degree of danger from the contents is based on classifications adopted in the directives on dangerous substances. A choice of conformity assessment procedures is proposed depending on the category of the equipment.

Manufacturers will generally be given a choice between a quality assurance module or a module which requires verification and approval by a Notified Body. Member States will appoint Notified Bodies which will normally be independent third parties, but in some circumstances User Inspectorates (second party inspection bodies) may be authorized.

Pressure equipment and assemblies which comply with the Directive will be required to carry the CE marking and will qualify for free circulation within the European Community.

1.5 Latest Position

A common position was reached in the European Council on 29 March 1996 which means that Member State Governments have agreed the terms of the proposal. The common position document then went to the European Parliament for it's second reading which it completed on 17 July 1996 and proposed fourteen amendments. The proposal has been returned to the Council of Ministers for final adoption and is currently the subject of intense discussion between the Council, the Commission and the European Parliament. As a result of such debate, adoption has been delayed and is now expected in early 1997. The Directive will enter into force two and a half years from adoption and will be mandatory two and a half years later.

2 Scope

2.1 General

The scope of the proposed Directive is fairly broad, in line with all new approach directives, and is given in Article 1 of the Directive, as follows:-

"design, manufacture and conformity assessment of pressure equipment and assemblies with a maximum allowable internal pressure PS greater than 0.5 bar."

The Directive therefore applies to such items as shell and water tube boilers, heat exchangers, pressure vessels, pressurised storage containers, industrial pipework and associated accessories. PS greater than 0.5 bar is defined as the maximum pressure for which the equipment is designed, relative to atmospheric pressure, i.e. gauge pressure.

2.2 Definitions

The term pressure equipment, for the purpose of this Directive, includes vessels, piping, safety accessories and pressure accessories and any components directly attached to pressure retaining parts, such as flanges, nozzles, couplings, supports and lifting lugs.

The Directive gives the following definitions:

Vessel: – a housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber.

Piping: – piping components intended for the transport of fluids, when connected together for integration into a pressure system.

Piping includes a pipe or system of pipes, tubing, fittings, expansion joints, hoses or other similar pressure bearing components.

Safety Accessories: – devices designed to protect pressure equipment against the allowable limits being exceeded.

Safety accessories include devices for direct pressure limitation, such as safety valves, bursting discs, buckling rods, controlled safety pressure relief systems (CSPRS) and limiting devices such as pressure, temperature and level switches, providing that they either activate the means for protection or provide input to a shutdown function. Warning devices are not classed as safety accessories as they do not carry out such a function.

Pressure Accessories: – devices with an operational function and having pressure bearing housings.

Pressure accessories include items such as filters, regulating or isolating valves, expansion joints and piping components.

Assemblies: – several pieces of pressure equipment assembled by a manufacturer to constitute an integrated and functional whole.

In this definition, the crucial phrase is, 'an integrated and functional whole.' This statement means that an item of pressure equipment that is made up of several different components and placed on the market as a complete unit must be assessed against the requirements of the Directive as a complete unit. However if the same equipment is sold as individual components and assembled together into a complete unit on site by the operator, then the complete unit is not required to satisfy the requirements of the Directive, although the individual components may still have to.

Pressure: – pressure relative to atmospheric pressure, i.e. gauge pressure. Maximum allowable pressure (PS) means the maximum pressure for which the equipment is designed, as specified by the manufacturer, at a location specified by the manufacturer. This point must be at the connection point of the safety devices, or the top of the equipment if appropriate.

Maximum/minimum Allowable Temperature (TS): – the temperatures for which the equipment is designed, as specified by the manufacturer.

Volume (V): – the internal volume of a chamber, including the volume of nozzles up to the first connection or weld, excluding the volume of any permanent internal components.

Fluids: – gases, liquids, vapours in pure phase as well as mixtures thereof. A fluid may contain a suspension of solids.

Permanent Joints: – any joint which cannot be disconnected except by destructive means.

2.3 Exclusions

As in all other directives, there are a number of items which are specifically excluded from this Directive because they are covered by existing or planned EC directives, there are no significant barriers to trade, or the hazards relating to the stored energy of the system are relatively low. The following list gives only a brief description of each exclusion and, for a more detailed description, the Directive itself should be referenced:

- pipelines outside the last isolating device within premises or installations
- stream waterways and pressure shafts for hydroelectric installations
- vessels covered by the Simple Pressure Vessels Directive (87/404/EEC)
- aerosols covered by Directive 75/324/EEC
- equipment for the functioning of vehicles covered by other EC directives
- equipment classified as no higher than category I by the Pressure Equipment Directive, where the hazards due to pressure are considered to be adequately addressed within these other directives. This exclusion is discussed in more detail in Section 5.3.

- equipment covered by Article 223(1)(b) of the EEC Treaty, i.e. weapon systems and firearms
- items designed for use in the nuclear industry, failure of which may cause an emission of radioactivity
- oil/gas drilling equipment upstream of the Christmas Tree
- engine/turbine casings or machinery where the main design considerations are primarily strength, rigidity and stability rather than pressure
- equipment for the production and casting of steel and non-ferrous metals
- enclosures for high-voltage electrical equipment
- pressurised pipes for the containment of transmission systems, e.g. for electrical, power and telephone cables
- equipment intended for the propulsion of, or installation on, ship, rockets, aircraft and mobile off shore units
- pressure equipment consisting of a flexible casing, e.g. tyres and balls
- exhaust and inlet silencers
- bottles and cans for carbonated drinks
- vessels designed for the transport and distribution of drinks
- equipment for the transportation of dangerous goods which are covered by 'The European Agreement concerning the International Carriage of Dangerous Goods by Road' (ADR), 'The Regulations concerning International Carriage of Dangerous Goods by Rail' (RID), 'The International Maritime Dangerous Goods Code' (IMDG) and the 'International Civil Aviation Organisation' (ICAO).
- radiators and pipes in warm water heating systems
- Vessels (storage tanks) designed to contain liquids with a gas pressure above the liquid of not more than 0.5 barg

3 Technical Requirements

The Directive states that pressure equipment and assemblies above certain thresholds of pressure/volume must satisfy a set of 'essential safety requirements' (ESR's) for their design, manufacture and testing. The Directive's ESR's relate to:

- General (ESR 1)
- Design (ESR 2)
- Manufacture (ESR 3)
- Materials (ESR 4)
- Fired/heated pressure equipment with a risk of over heating (ESR 5)
- Piping (ESR 6)
- Safety factors for certain pressure equipment (ESR 7)

All these ESR's must be considered, and manufacturers must comply with them if a hazard associated with a particular ESR exists when equipment is used under conditions which are reasonably foreseeable by the manufacturer. This may require the manufacturer to undertake some form of risk analysis to determine which hazards could exist under all normal, and reasonably foreseeable fault conditions.

The ESR's are not applicable to equipment below the pressure/volume thresholds. This equipment has only to be designed and manufactured in accordance with "sound engineering practice" recognised in a Member State. Further details on this type of equipment will be discussed later.

Details of each ESR are given in the following sections.

3.1 ESR 1 – General

This ESR is little more than an introduction to the ESR's and simply states that all pressure equipment must be designed and manufactured in such a way as to ensure its safety when put into service in accordance with the manufacturer's instructions or in reasonably foreseeable conditions. This includes danger resulting from potential misuse. To achieve this, the manufacturer must apply the following basic principles in the following order:

- Eliminate or reduce hazards as far as is reasonably practicable
- Protect against hazards which cannot be eliminated
- Highlight residual hazards and indicate special measures to be taken to reduce the risk.

3.2 ESR 2 – Design

The Directive requires that all pressure equipment is properly designed, manufactured, equipped and installed to ensure its safety when put into service in accordance with the manufacturer's instructions. The factors which must be taken into consideration during the design process are covered in the following sub sections.

3.2.1 Design for Adequate Strength

The design of the pressure equipment must allow for all loadings, or combinations of loadings, appropriate to its intended use. In particular, the following loadings must be considered:

- internal/external pressures
- temperature
- static pressure
- mass of contents
- traffic or wind
- earthquake
- reaction forces and moments from supports, attachments, piping etc.
- corrosion or erosion
- fatigue
- decomposition of unstable fluids

The design must incorporate adequate safety margins against all foreseeable failure modes and must be based, at the manufacturer's choice, on either a calculation method supported by testing if necessary, or an experimental design method without any calculations. However, the experimental method can only be used when the product of working pressure and volume (PS.V) is less than 6000 bar.litres for vessels, or the product of working pressure and nominal size (PS.DN) is less than 3000 bar for piping.

3.2.1.1 Design by Calculation

Calculations must be based on one, or a combination, of the following; design by formula, analysis or fracture mechanics and must provide sufficient safety margins consistent with the safety factors specified in ESR 7. Where factors of safety, other than those given in ESR 7, are used, these must be justified in the calculations. Consideration must be given to all actual and reasonably foreseeable operating conditions, and the properties and behaviour of the materials to be used.

The pressure used in the calculations must not be less than the maximum allowable pressure and must take into account static head, dynamic fluid pressures and the decomposition of any unstable fluids. Material properties used must correspond to the working temperature of the pressure equipment and the design must take into account all possible combinations of temperature and pressure. Where a vessel is separated into more than one pressure containing chamber, the design of the partition wall must be based on the maximum pressure difference that can occur between chambers.

The design must also include joint factors appropriate to the type and level of non-destructive examination (NDE) which must be applied to the material properties. Consideration must also be given to any reasonably foreseeable process of degradation, such as corrosion, erosion, fatigue or creep. In particular, users of the pressure equipment must be advised in the instruction manual of any factors relevant to the life of the equipment, such as the design life at a specific operating temperature or the number of operating cycles at a specific stress level.

Not withstanding the above design considerations, the Directive also states that pressure equipment must have suitable structural stability. This means that if the calculated thickness is very low, the equipment must still be manufactured from a suitable thickness to prevent collapse or distortion during handling, or from impact with other objects.

3.2.1.2 Experimental Design Method

The experimental design method involves carrying out an agreed programme of tests on a representative sample of the pressure equipment. The test programme must be acceptable to the Notified Body responsible for the design conformity assessment module, where a Notified Body is required to be involved, and it must define the test conditions and the criteria for acceptance or rejection.

The test programme must include a pressure strength test with a defined safety margin relative to the design pressure, to demonstrate that the equipment does not leak or deform beyond an agreed acceptance criteria. The test pressure must be determined based on the differences between the actual geometric and material properties under test and those used in the design, and must also take into consideration the difference between test and operating temperatures.

If the pressure equipment is subject to external loading, corrosion, creep or fatigue, then additional testing may be required to verify that the lifetime service conditions for the equipment can be achieved.

3.2.2 Provisions to ensure safe handling and operation

The Directive requires that pressure equipment is designed and operated so as to avoid any reasonably foreseeable risk during the operation of the equipment. Therefore attention must be given to the following, where applicable:

- closures and openings
- discharge of pressure relief blow-off
- devices to prevent access whilst a pressure, vacuum or temperature hazard exists
- surface temperature
- decomposition of unstable fluids

Where equipment has an access door, this must be fitted with an automatic or manual device which enables the operator to ascertain that the equipment may be opened without any risk. Additionally, if an opening can be opened quickly, then it must incorporate a device which prevents it from being opened whenever there is risk to the operator from either pressure or temperature.

3.2.3 Means of examination

Pressure equipment must be designed and constructed to allow examinations to be carried out to determine the condition of the equipment.

Means of examining the internal condition of the equipment must also be available where necessary, such as openings allowing physical access. Other means of ensuring the safe condition of the equipment may be used if:

- the equipment is too small for physical access
- opening the equipment would adversely affect the interior
- the equipment contains fluids which are not harmful to the material and there are no other foreseeable means by which internal degradation can be caused.

3.2.4 Draining, venting, filling and discharge

Pressure equipment must be designed to allow adequate means for venting and draining to avoid effects such as water hammer, vacuum collapse, corrosion and uncontrolled chemical reactions during all stages of operation and testing, and to allow cleaning, inspection and maintenance in a safe manner.

During filling and discharge operations, means must be provided to prevent overfilling or over-pressurisation and the uncontrolled release of the pressurised fluid. The design must prevent unsafe connection or disconnection of fittings.

3.2.5 Corrosion, chemical attack and erosion

The design of pressure equipment must make suitable allowances for protection against corrosion or chemical attack or severe conditions. Their effects should be minimised wherever possible by appropriate design, such as additional material thickness, liners or cladding, replacement of affected parts or by detailing measures to be taken in the instruction manual.

3.2.6 Protection against exceeding allowable limits

The design must include provisions for the fitting of devices to prevent allowable limits of pressure being exceeded where this could be possible. Suitable devices could be safety accessories or indicators/alarms which enable preventative action to be taken either automatically or manually.

Where an item of pressure equipment is part of an assembly, protective devices may be elsewhere within the assembly, provided that they give adequate protection to the full assembly.

3.2.7 Safety accessories

The Directive requires that safety accessories must be designed and manufactured so as to be reliable and suitable for their intended duty. Their operation must be independent of other functions, unless it can be shown that their safety function cannot be affected by any other feature. Where possible, the design of safety accessories should be based on fail-safe, redundancy, diversity and self-diagnosis principles.

Pressure limiting devices should ensure that the pressure does not exceed the maximum allowable pressure (PS), although a pressure surge of short duration may be allowed. Temperature limiting devices must have an adequate response time consistent with their function.

3.3 ESR 3 – Manufacture

The Directive requires that the manufacture of pressure equipment must be undertaken using suitable procedures and qualified personnel to ensure that the design requirements are achieved.

All material used must be fully traceable through all stages of manufacture, and the preparation of component parts must not cause any defects or cracks or changes to the material properties that may be detrimental to the safety of the equipment.

3.3.1 Joining

Throughout the Directive, reference is made to joining operations rather than welding as the Directive is not specific to steel or metallic equipment and applies equally to glass, plastic, GRP or other materials.

All permanent joints must have material properties at least equal to those of the parent material and be carried out by approved personnel in accordance with suitably approved procedures. This requirement also applies to joints attaching components to pressure retaining parts. For pressure equipment and assemblies which are classified by the Directive in categories II, III and IV, the procedures and personnel must be approved by either a Notified Body or a third party organisation recognised by a Member State.

Non destructive testing of joints must be carried out by qualified personnel, and for pressure equipment in categories III and IV personnel must be approved by a Notified Body or recognised third party.

If the manufacturing and joining operations are such that the material properties may be reduced to below a safe level, then a suitable heat treatment procedure must be undertaken to restore them to the design requirements.

3.3.2 Final assessment

Final assessment must be carried out for all items of pressure equipment. Final assessment must consist of an internal and external visual inspection of all components, a document review and a hydrostatic pressure test. For equipment in category I the pressure test may be carried out on a statistical sample taken from the production. For equipment where a hydrostatic test may be impracticable or harmful, other recognised tests may be carried out.

For pressure vessels, the test pressure should be not less than the greater of:

- that corresponding to the maximum loading to which the pressure equipment may be subject in service taking into account its maximum allowable pressure and its maximum allowable temperature, multiplied by the coefficient 1.25, or
- the maximum allowable pressure multiplied by the coefficient 1.43

The final assessment of assemblies must include a test of the safety devices fitted to prevent over-pressurisation.

3.3.3 Marking

In addition to the 'CE' marking, the following information must be provided for all pressure equipment:

- identification of the manufacturer
- year of manufacture
- identification of the pressure equipment, such as type and serial number
- maximum/minimum allowable limits

Any further information necessary for safe installation, operation or use, maintenance or inspection should also be provided, and any warnings against misuse must be fixed to the equipment.

The 'CE' marking and necessary information must be on

the equipment or a data-plate attached to it. However where the equipment is too small it may be given on a firmly affixed label. Documentation may also be used to avoid repetitive marking of individual parts, such as piping, intended for the same assembly.

3.3.4 Operating Instructions

All items of pressure equipment must, when placed on the market, be accompanied with adequate instruction to allow the purchaser to assemble, put into service, use and maintain the equipment in a safe manner.

The instructions must include all the data listed on the nameplate (with the exception of the serial number) and contain all the necessary technical documentation (drawings etc.) necessary for the operator to have a full understanding of the equipment. The instructions must draw to the attention of the user any hazards which may arise from misuse.

3.4 ESR 4 – Materials

All material used for the manufacture of pressure equipment must have suitable properties for its intended use and be sufficiently resistant to corrosion by the process fluid for the intended lifetime of the equipment.

Material for pressurised parts should be sufficiently ductile and tough for all operating and test conditions and should not be significantly affected by ageing.

The manufacturer must define in his technical documentation the mechanical and chemical properties necessary to satisfy his design requirements and must obtain from the material manufacturer certification to confirm that the material conforms to the required specification. For pressure equipment in categories II, III and IV, this must be a certificate of specific product control.

Materials selected must fall into one of the following categories:

- comply with a harmonised standard
- be covered by a European approval of pressure equipment material by a Notified Body in accordance with Article 11 of the Directive
- be subject to a particular material appraisal, which for equipment in categories III and IV must be carried out by the Notified Body involved in the conformity assessment

3.5 ESR 5 – Heated Pressure Equipment – Specific Requirements

This ESR gives specific requirements which are additional to those in ESR's 1 to 4, and applies to pressure equipment which is fired or heated by other means with a risk of overheating.

Equipment covered by this ESR would be steam and hot water generators which produce steam or super-heated water at a temperature greater than 110°C. This includes fired boilers, super-heaters, re-heaters, waste heat boilers, waste incineration boilers, electrically heated boilers and pressure cookers, and includes any accessories and systems for treatment of feedwater and fuel. Process heating equipment such as heaters for chemical processes and pressurised food processing equipment are also covered by this ESR.

The Directive requires that heated pressure equipment is designed and constructed to minimise the risk of a loss of containment due to overheating. Attention must be given to:

- providing suitable means of protection to avoid local and general overheating, by restricting operating parameters such as heat input and fluid level
- providing sampling points so that fluid properties can be monitored to reduce risks due to corrosion and deposits
- adequate means for removing residual heat after shutdown
- prevention of a dangerous build up of combustible substances or flame blowback.

3.6 ESR 6 – Piping – Specific Requirements

This ESR lists specific requirements for piping systems which must be addressed in addition to those given in ESR's 1 to 4. The design and construction of pipework must consider:

- the over-stressing of flanges, bellows etc. due to free movement. The movement must be adequately controlled by the provision of suitable supports, anchoring, alignment and pre-tensioning
- the provision for drainage and removal of condensation in gaseous systems to prevent damage from water hammer or corrosion
- the effects of turbulence and the formation of vortices, especially where the fluid flow pattern could induce wear in the pipework
- fatigue due to vibration
- that where hazardous (Group 1) fluids are contained, take-off points in pipes which are large enough to present a hazard to personnel must be capable of isolation
- that take-off points must be clearly marked on the permanent side, indicating the fluid contained, to reduce the risk of inadvertent discharge
- that the position and route of all underground pipework must be recorded in the technical documentation to facilitate safe maintenance

3.7 ESR 7 – Specific Quantitative Requirements for Certain Pressure Equipment

This ESR lists various safety factors which are to be applied in certain circumstances, and supplement the requirements given in ESR's 1 to 6 for the pressure equipment to which they apply. However, these factors apply as a general rule only, and may be varied although, where they are not applied, the manufacturer must demonstrate that appropriate measures have been taken to achieve an equivalent overall level of safety.

3.7.1 Allowable Stresses

The maximum permissible general membrane stress for static pressure loading for equipment being operated outside the temperature range where creep is significant should not exceed the lower of the values given in Table I for the material used.

Table I
Allowable Stresses

Material	Allowable Stress	
Ferritic steel	$\sigma_y/1.5$	$\sigma_u/2.4$
Austenitic steel:		
elongation ≥ 30%	$\sigma_{y1}/1.5$	
elongation ≥ 35%	$\sigma_{y1}/1.2$	$\sigma_{ut}/3$
non alloy or low alloy cast steel	$\sigma_y/1.9$	$\sigma_u/3$
aluminium	$\sigma_{y1}/1.5$	
aluminium alloy	$\sigma_y/1.5$	$\sigma_u/2.4$

where, σ_y: 0.2% yield stress at design temperature
σ_{y1}: 1% yield stress at design temperature
σ_u: ultimate strength at 20°C
σ_{ut}: ultimate strength at design temperature

3.7.2 Joint Coefficients

The design of pressure equipment must include joint coefficients for welded joints, which must not be greater than:

1.0: for equipment subject to 100% non-destructive examination to show that the joints contain no unacceptable defects.

0.85: for equipment subjected to random non-destructive examination only.

0.7: for equipment not subject to any non-destructive examination other than visual examination.

3.7.3 Material Characteristics

A steel is considered to be ductile if its elongation after rupture is greater than 14%, and its impact strength measured on a standard ISO V test-piece at 20°C, or the lowest design operating temperature is greater than 27 Joules.

4 Categorisation of Pressure Equipment

4.1 General

The Directive categorises pressure equipment into four categories depending on the risk associated with pressure. Category I is the lowest risk category, while category IV applies to equipment presenting the highest level of risk.

The category is established by taking into consideration the type of the pressure equipment (i.e. vessel, steam generator, piping or accessory), the nature of the fluid contained, the fluid state (liquid or gas), the working pressure, and the volume of a vessel or the nominal size (DN) of pipework.

4.2 Fluid Groups

Article 9 of the Directive divides fluids into two different groups. Group 1 comprises dangerous fluids, with all other fluids comprising Group 2. A summary of the fluid groups is given in Table II.

Table II
Fluid Groups

Group 1	• explosive • extremely flammable • highly flammable • flammable (where the maximum allowable temperature is above flashpoint) • very toxic • toxic • oxidising
Group 2	• all other fluids not referred to in Group 1

4.3 Conformity Assessment Tables

Annex II of the Directive gives nine diagrams which are used to determine the category for each item of pressure equipment. Each diagram relates to a specific type of pressure equipment and plots pressure against either volume (for vessels) or pipe size DN (for pipework). The nine diagrams, which are referred to as Tables in the Directive, are reproduced in Appendix D and can be summarised as follows:

Table 1: vessels containing Group 1 gases, vapours and liquids with a vapour pressure at the maximum working temperature of greater than 0.5 barg above atmospheric pressure. Additionally, vessels which fall into categories I or II containing an unstable gas must be classified in category III.

Table 2: vessels containing Group 2 gases, vapours and liquids with a vapour pressure at the maximum working temperature of greater than 0.5 barg above atmospheric pressure. Additionally,

portable extinguishers and bottles for breathing equipment which fall into categories I or II must be classified in category III.

Table 3: vessels containing Group 1 liquids.

Table 4: vessels containing Group 2 liquids.

Table 5: fired or heated pressure equipment for generating steam or superheated water at a temperature greater than 110°C with a risk of overheating. Additionally, all pressure cookers must be classified as at least category III.

Table 6: piping for Group 1 gases, vapours and liquids with a vapour pressure at the maximum working temperature greater than 0.5 barg above atmospheric pressure. Additionally, piping for unstable gases which fall into category I or II must be classified as category III.

Table 7: piping for Group 2 gases, vapours and liquids with a vapour pressure at the maximum working temperature greater than 0.5 barg above atmospheric pressure. Additionally, piping for fluids with an operating temperature above 350°C which falls in category II must be classified in category III.

Table 8: piping for Group 1 liquids.

Table 9: piping for Group 2 liquids.

4.4 Safety Accessories

All safety accessories are classified as category IV, except that safety accessories manufactured for a specific item of pressure equipment may be classified in the same category as the item of equipment it protects.

4.5 Pressure Accessories

Pressure accessories are classified in the same way as for vessels and pipework, by using the appropriate assessment table. Where both nominal pipe size and vessel volume are appropriate, a pressure accessory must be classified in the highest risk category.

4.6 Pressure Equipment Below Set Thresholds

Each assessment table has a lower limit below which none of the categories apply. Pressure equipment that falls into this category must be designed and manufactured in accordance with "sound engineering practice" which is accepted by a Member State, rather than the essential safety requirements specified in Annex I of the Directive. Such equipment is not 'CE' marked but must have adequate instructions to allow it to be operated safely, and have suitable markings to allow the manufacturer to be identified.

5 Routes to Attestation

5.1 General

Article 10 of the Directive states that manufacturers must submit the design and method of manufacture of each item of pressure equipment to one of the conformity assessment procedures, or modules, described in Annex III of the Directive. The choice of module, or modules available to the manufacturer is dependent on the category of the pressure equipment. These modules are based on the EC Modules Decision 93/465/EEC.

The manufacturer therefore has a degree of choice enabling him to select a conformity assessment route which most closely corresponds to his current practice and situation.

5.2 Categories

Having established the category applicable to the item of pressure equipment, Article 10 of the Directive details the choice of module(s) available to the manufacturer to demonstrate compliance with the Directive, and these are shown in Table III.

Table III
Conformity Assessment Modules

Category	Module(s)
I	A
II	A1 or D1 or E1
III	B1 + D or B1 + F or B + E or B + C1 or H
IV	B + D or B + F or G or H1

5.3 Exempt Equipment

The scope of the Directive states that pressure equipment classified as category I which is also covered by certain other directives is exempt from the Pressure Equipment Directive as any risk due to pressure is adequately covered by the essential requirements of the other directive. The applicable directives are:

- Machinery 89/392/EEC
- Lifts 95/16/EC
- Low voltage 73/23/EEC
- Medical devices 93/42/EEC
- Appliances burning gaseous fuels 90/396/EEC
- Equipment for potentially explosive atmospheres 94/9/EC

6 Conformity Assessment Modules

There are a total of thirteen different conformity assessment modules or combinations of modules from which a manufacturer can select. He may, if he wishes, select a higher module(s) than that required for the category of his pressure equipment.

Below is a brief description of each of the modules. For each module, the requirements for the technical documentation which the manufacturer is required to compile are discussed in Appendix A.

6.1 Module A – Internal Control of Manufacture

This Module can only be used for category I equipment and requires the manufacturer, or his authorised representative within the Community, to prepare all the necessary technical documentation and to demonstrate that the equipment is in conformity with the requirements of the Directive. He must retain the documentation for a period ten years after the last date of manufacture and be able to make it available to the authorities if requested.

The manufacturer, or his authorised representative must draw up a written Declaration of Conformity and apply the 'CE' marking to the equipment.

It is the manufacturer's responsibility to ensure that the methods of production ensures that the manufactured equipment is in accordance with the design, and to carry out the final assessment, which may be done on a statistical basis.

6.2 Module A1 – Internal control with monitoring of the final assessment

Module A1 relates to category II equipment and as in Module A the manufacturer is responsible for preparing and retaining the necessary technical documentation verifying his design. However, in addition to the requirements of Module A, a Notified Body must ensure that the manufacturer performs the final assessment on each item of equipment and review the manufacturing records.

This would entail the Notified Body monitoring the final assessment by random visits and may also, if it considers it necessary, take samples and perform, or have performed, prescribed tests to demonstrate conformity.

The manufacturer draws up a written Declaration of Conformity and affixes the 'CE' marking together with the identification number of the Notified Body responsible for the production surveillance, on each piece of pressure equipment.

6.3 Module B – EC Type Examination

This Module relates to the design aspects of the pressure equipment only, and has to be used in combination with one of the associated production modules.

The manufacturer submits his technical documentation to a Notified Body and makes available a representative sample of the pressure equipment to be produced. The sample, or 'type,' may cover several versions of the pressure equipment provided that the differences between the versions do not effect the level of safety.

The Notified Body must review the technical documentation and verify that the sample has been manufactured in accordance with the Directive, appraise the materials used, the suitability of the joining processes and the qualifications and approvals of the personnel carrying out the joining and NDT operations. It must then perform, or have performed, any necessary tests to demonstrate that the design meets the requirements of the Directive or any harmonised standard that the designer may have applied.

Following satisfactory review of the technical documentation and testing, the Notified Body will issue the manufacturer with an EC Type Examination Certificate which is valid for ten years and is renewable. The manufacture must keep the certificate together with the technical documentation for a period of ten years after the last date of manufacture of the pressure equipment, and is required to inform the Notified Body that issued the EC Type Examination Certificate of any subsequent modifications to the pressure equipment which may effect the level of safety.

6.4 Module B1 – EC Design Examination

EC design examination is similar to Module B (Type Examination) and only relates to the design aspects of the pressure equipment with the production being covered by either Module D or Module F.

For this Module, the manufacturer must submit his technical documentation to a Notified Body who will review it to confirm that the design meets the harmonised standard which the manufacturer has applied or that it meets the Directive's requirements where a harmonised standard has not been used. The Notified Body will also appraise the materials, joining processes and qualifications and approvals of personnel carrying out the joining and NDT operations. The Notified Body must perform, or have performed, tests to verify the design meets the Directive's requirements where a harmonised standard has not been used.

Following a satisfactory review of the technical documentation and any necessary test reports, the Notified Body will issue an EC Design Examination Certificate. The manufacturer must add the certificate to the technical documentation, which must be retained for a period of ten years after the last date of manufacture, and is responsible for informing the Notified Body of any modifications to the approved design.

It should be noted that this Module cannot be used for equipment designed using the experimental method discussed in Annex I of the Directive.

6.5 Module C1 – Conformity to Type

Module C1 relates to production only and can only be used in conjunction with Module B (Type Examination). This combination of Modules (B and C1) can only be used for category III pressure equipment.

For this Module, the manufacturer is responsible for producing the pressure equipment in conformity with the approved design and manufacturing methods that are covered by an EC Type Examination Certificate issued by a Notified Body.

In addition, final assessment is also subject to random surveillance visits by a Notified Body.

The manufacturer must draw up a written declaration of conformity and affix the 'CE' marking to all items of pressure equipment together with the identification number of the Notified Body responsible for surveillance. The Directive does not require that the Notified Body responsible for surveillance must be the same body that issued the EC Type Examination Certificate.

6.6 Module D – Production Quality Assurance

This Module relates to production aspects only and has to be used in combination with either Module B1 (design examination) for category III equipment, or Module B (type examination) for category IV.

For this Module, the manufacturer must operate, and have accepted by a Notified Body, a Quality Assurance system (equivalent to ISO 9002) which assures that the production, final assessment and testing of the pressure equipment will conform to the approved design as described in the EC Type Examination or EC Design Examination certificate.

The manufacturer must submit to the Notified Body details of the quality system including the quality objectives, organisation structure and responsibilities. It must detail the manufacturing controls, examination and tests that will be carried out and the records that will be retained, together with the methods of internal monitoring of the effectiveness of the quality system.

The Notified Body which has approved the quality assurance system must carry out periodic audits of the quality system, and may, if it considers it necessary, carry out, or have carried out, actual tests of the pressure equipment. At least one member of the auditing team must have suitable experience in pressure equipment technology.

The manufacturer draws up a written declaration of conformity and affixes the 'CE' marking together with the identification number of the Notified Body that approved the quality system and carries out the surveillance.

6.7 Module D1 — Production Quality Assurance

Module D1 is for category II equipment and relates to production aspects only. The manufacturer is responsible for producing the technical documentation to verify that the design meets the requirements of the Directive.

The manufacturer must additionally operate a quality system (equivalent to ISO 9002) which has been approved by a Notified Body, for the manufacture, final assessment and testing which ensures that the manufactured items of pressure equipment satisfies the requirements of the Directive. The manufacturer must submit to the Notified Body details of the quality system and the technical documentation for the pressure equipment.

The Notified Body must carry out periodic audits of the quality system, and if necessary have tests carried out.

The manufacturer draws up a written declaration of conformity, affixes the 'CE' marking and the identification number of the Notified Body that approved the quality system and carries out the surveillance.

6.8 Module E – Product Quality Assurance

Module E relates to production aspects only, and has to used in conjunction with Module B (type examination) for category III pressure equipment only.

This Module requires the manufacturer to operate and have approved by a Notified Body a quality system equivalent to ISO 9003 for the final assessment and testing for each item of pressure equipment.

The Notified Body that has approved the quality system must carry out periodic audits of the quality system and have carried out any testing it considers necessary.

The manufacturer draws up a declaration of conformity, affixes the 'CE' marking and the identification number of the Notified Body that approved the quality system and caries out the surveillance.

6.9 Module E1– Product Quality Assurance

This Module is for category II equipment only and relates to production aspects only.

The manufacturer is responsible for the design, and must operate, and have approved by a Notified Body, a quality system equivalent to ISO 9003 to ensure that the production and testing of each item of pressure equipment meets the requirements of the Directive. The technical documentation for the design must be submitted to the Notified Body that approves the quality system.

The Notified Body carries out periodic audits of the quality system, and may, if necessary, have tests carried out.

The manufacturer draws up a declaration of conformity, affixes the 'CE' marking and the identification number of the Notified Body that has approved the quality system.

6.10 Module F – Product Verification

Module F relates to manufacturing aspects only and has to be used in conjunction with either Module B1 (design examination) for category III equipment, or Module B (type examination) for equipment in category IV.

A Notified Body must witness the final assessment on each item of equipment to verify that it conforms with either the EC Design Examination or EC Type Examination Certificate.

Following satisfactory testing, the Notified Body will issue to the manufacturer an EC Certificate of Conformity and the manufacturer will draw up his Declaration of Conformity, affix the 'CE' marking and the identification number of the Notified Body responsible for product verification.

6.11 Module G – EC Unit Verification

This Module is for category IV equipment and requires the manufacturer to submit to a Notified Body all the technical documentation relating to the design and manufacture of each item of pressure equipment, and is hence more appropriate to one-off items.

The Notified Body must review the technical documentation and have carried out any necessary tests, including final assessment, to verify that the design meets the requirements of the Directive, which should include an appraisal of the materials, joining processes and the qualifications of the personnel carrying out the joining operations and NDT.

The Notified Body issues to the manufacturer an EC Certificate of Conformity, and the manufacturer draws up a declaration of conformity, affixes the 'CE' marking and the identification number of the Notified Body. The manufacturer retains the technical documentation, including the Notified Bodies certificate of conformity, for a period of ten years.

6.12 Module H – Full Quality Assurance

Module H is for category III equipment and requires the manufacturer to operate, and have approved by a Notified Body a quality assurance system equivalent to ISO 9001 which ensures that all aspects of the design, manufacture and final assessment of the pressure equipment complies with the requirements of the Directive.

The manufacturer must submit to the Notified Body, for approval, full details of the quality system, which in addition to the information required for Module D must include all details of design control, verification and standards or specifications that will be used to ensure the design complies with the Directive.

The Notified Body will carry out periodic audits of the quality system and may also make unexpected visits, if it considers it necessary, during which it may have carried out any tests it considers necessary to verify that the quality system is functioning correctly. The auditing team will include at least one person who has relevant experience in pressure equipment technology.

The manufacturer draws up a declaration of conformity, affixes the 'CE' marking and the identification number of the Notified Body responsible for approving the quality system and carrying out surveillance.

6.13 Module H1 – Full Quality Assurance with Design Examination

This Module is for category IV equipment and requires the manufacturer, in addition to operating a quality system that meets the requirements of Module H, to submit the technical documentation to a Notified Body for approval. The Notified Body will issue an EC Design Examination Certificate when it is satisfied that the design complies with the Directive.

The quality system will be subject to audits by the Notified Body, and final assessment will be subject to a greater frequency of audit than for Module H, during which the Notified Body must witness the actual final assessment.

The manufacturer draws up a declaration of conformity, affixes the 'CE' marking and the identification number of the Notified Body that approved the quality system.

6.14 Summary of Modules

To summarise the available modules and combinations of modules, it can be seen how the involvement of a Notified Body increases as the risk category of the pressure equipment increases. Category I equipment does not require a Notified Body to be involved, category II requires surveillance of the final assessment, category III requires EC type examination and surveillance of the final assessment and Category IV requires type examination and verification of the final assessment for each item of pressure equipment.

Modules B and B1 (type examination and design examination) appear to be very similar, although Module B1 is limited to category III equipment. However B1 can only be used with Module F (verification) which therefore makes it more applicable to one off items of pressure equipment rather than series produced items.

For the quality assurance related modules (D, D1, E, E1, H and H1), the Directive requires a quality management system equivalent to the ISO 9000 series, which must also address all the requirements of the Directive. For manufacturers who are already ISO 9000 certified, an additional assessment of their quality system will be required to confirm that the requirements of the Directive are covered, as some of these may well be additional to those of ISO 9000.

7 EC Declaration of Conformity

All items of pressure equipment, when placed on the market, must be accompanied by a Declaration of Conformity signed by an authorised representative of the manufacturer, or his agent in the EU, or the person responsible for importing the equipment into Europe and placing it on the market. This is a legal document in which the manufacturer declares that the items to which it refers comply with the requirements of the Pressure Equipment Directive, and any other directive which is applicable to that item for which a similar conformity assessment procedure has been applied in accordance with the requirements of that particular directive.

The Directive requires the Declaration of Conformity to include the following information:

- Name and address of the manufacturer or his authorised representative in the Community
- Description of the pressure equipment or assembly
- For assemblies, a description of the items making up the assembly
- Conformity assessment Module(s) followed, i.e. A, B + F, H1
- Names and addresses of any Notified Bodies which have been involved in either inspection or approval of the quality system. There can be more than one body
- Reference to any EC Type Examination, EC Design Examination or EC Certificates of Conformity that may have been issued by a Notified Body
- Reference to any Harmonised standards that may have been used
- Reference to any other standards that may have been used, such as ASME VIII or BS 5500
- Any other directive that may be applicable to the item or assembly of pressure equipment which the manufacturer is declaring conformity with
- Particulars of the person signing this legally binding declaration on behalf of the manufacturer

8 Safeguard Clause

As in other new approach directives, the Pressure Equipment Directive has a safeguard clause whereby Member States who have reason to believe that items of pressure equipment or assemblies that are CE marked and being correctly used in accordance with their instructions present a hazard to people, property or domestic animals, they are authorised to withdraw such equipment from the market.

The Member State must immediately inform the Commission of their action, stating their reasons. The Commission shall consult with all concerned parties without delay. Typical reasons for taking such action could be failure to comply with the Directive's ESR's, failure to correctly apply a harmonised standard or even shortcomings in a harmonised standard. After consultation, which may involve referral to a Standing committee, the Commission will advise the Member State of their findings, and if justified, appropriate action will be taken against the manufacturer to remove the equipment from the market.

9 Concluding Remarks

The Pressure Equipment Directive is primarily concerned with free trade rather than safety and will allow EU manufacturers free entry throughout the Union. It will be of particular significance in removing barriers to important sections of a very large market presently denied by current legislation.

LR is already a major international provider of independent third party assessment and certification services to clients in this area of core business and fully intends being appointed as a Notified Body under this new Directive. To be successful, LR will need to exploit its international network of contacts and follow a harmonized approach to maximize its share of this emerging market when it comes into force in 1999. From this date manufacturers will be able to manufacture, mark and sell freely equipment covered by the Directive in the European Union even though it will not be mandatory to do so until early 2002.

This Paper seeks to provide surveyors with a reference document allowing for informed debate with colleagues and clients alike – we trust it succeeds.

Appendix A – Technical Documentation

A.1 Composition

The documentation produced by the manufacturer can be divided broadly into two overlapping elements. These are:

I) quality documentation – procedures and manuals which define how the quality system is operated and the records generated by the system which demonstrate compliance with the quality system requirements of the Directive and ISO 9000.

II) technical documentation – product specific drawings, records and reports required to demonstrate compliance with essential requirements. The technical documentation must be controlled within the quality system.

Therefore, the procedure which states how, when and by whom risk analysis must be conducted is a quality system procedure; the records of the process are quality records/documentation. The results of the risk analysis, the solutions adopted and their implementation forms part of the technical documentation. Similarly, the design control procedures form part of the quality documentation, while the outputs of the process, e.g. drawings, test results, verification and validation results, are technical documentation.

In some cases, a clear distinction cannot be drawn between the two elements, e.g. a welding procedure may be considered to be either quality or technical documentation. In general, this overlap is not a problem providing the procedure is controlled within the system and implemented by appropriately trained personnel.

A general description of the technical documentation which the manufacturer must hold is contained within the Directive. Technical documentation must exist for all products to be covered by the quality system approval.

Annex III of the Directive, 'Conformity Assessment Procedures', states that the technical documentation must enable an assessment to be made of the conformity of the pressure equipment with the requirements of the Directive which apply to it. It must, as far as is relevant for such assessment, cover the design, manufacture and operation of the pressure equipment.

It is the specific auditing and evaluation of the technical documentation and the judgement made by the assessor regarding compliance with the essential requirements, which differentiates assessments for Directive from usual quality management system assessments.

The extent to which the technical documentation is audited and evaluated will be dependent upon the quality system Module concerned.

For Modules A, A1, B, B1, D1, E1 and G, the technical documentation must contain:

- a general description of the pressure equipment;
- conceptual design and manufacturing drawings and diagrams of components, sub-assemblies, circuits, etc.;
- descriptions and explanations necessary for an understanding of the drawings and diagrams and the operation of the pressure equipment;
- a list of the harmonised standards, applied in full or in part, and descriptions of the solutions adopted to meet the essential requirements of the Directive where the harmonised standards have not been applied;
- results of the design calculations made, examinations carried out, etc.;
- test reports (Note: this is not applicable to Modules B1 and G);
- information concerning the tests provided for in manufacture (Note: this is not applicable to Modules A, A1 and B1);
- information concerning the joining and non destructive examination qualifications or approvals required under the Directive (Note: this is not applicable to Modules A and A1);
- the necessary supporting evidence for the adequacy of the design solution, in particular where the harmonised standards have not been applied in full; this supporting evidence must include the results of tests carried out by the appropriate laboratory of the manufacturer or on his behalf (Note: this is only applicable to Module B1);
- the documentation concerning the quality system [QA documentation] (Note: this is only applicable to Modules D1 and E1).

For Modules C1, D, E, F, H and H1, the technical documentation must contain:

- all relevant information on the pressure equipment concerned [QA documentation] (Note: this is not applicable to Modules C1 and F);
- the documentation concerning the quality system [QA documentation] (Note: this is not applicable to Modules C1 and F);
- a copy of the EC type-examination certificate or EC design-examination certificate together with associated documentation [QA documentation] (Note: this is not applicable to Modules H and H1);
- the technical design specifications (Note: this is only applicable to Modules H and H1);
- the necessary supporting evidence for the adequacy of the design solution, in particular where the harmonised standards have not been applied in full; this supporting evidence must include the results of tests carried out by the appropriate laboratory of the manufacturer or on his behalf (Note: this is only applicable to Module H1).

Modules C1 and F cover the production phase only, the technical documentation have been included by the design phase of Module B or B1. Production or product quality assurances Module D or E also covers the production phase only and the relevant information on the pressure equipment concerned as required in QA documentation should include the technical documentation as listed in the design phase of Module B or B1. Full quality assurance Modules H and H1 which relate to both the design and production phases, the relevant information on the pressure equipment concerned should include the technical documentation as listed in Module B.

It is noted that technical design specifications are only required for Modules H and H1 in accordance with the Directive. However, this document should be included for other Modules when it is requested by the purchaser.

Table A.1 summarises the requirements of technical documentation for each module. These are minimum requirements and may be extended subject to the agreement between the manufacturer, purchaser and Notified Body.

Table A.1
The requirements of Technical Documentation for each Module

	Module												
Technical Documentation:	A	A1	B	B1	C1	D	D1	E	E1	F	G	H	H1
A general description of the pressure equipment	X	X	X	X			X		X		X		
Conceptual design and manufacturing drawings	X	X	X	X			X		X		X		
Descriptions and explanations necessary to understand drawings	X	X	X	X			X		X		X		
List of the harmonised standards applied and solutions adopted	X	X	X	X			X		X		X		
Results of calculations, examinations, etc.	X	X	X	X			X		X		X		
Test reports	X	X	X				X		X		X		
Information concerning the tests provided for in manufacture			X								X		
Information concerning the joining and non destructive examination qualifications or approvals			X	X							X		
Support evidence for adequacy of design solutions				X									X
All relevant information on pressure equipment (QA Documenation)						X		X				X	X
Documentation concerning quality system (QA Documentation)						X	X	X	X			X	X
Copy of EC type examination or design examination certificate together with associated documentation (QA Documentation)					X	X		X		X			
Technical design specification												X	X

A.2 Use of Design Calculations

For Modules B, B1, G and H1, the Notified Body must examine the technical documentation and identify the components which have been designed in accordance with the relevant provisions of the harmonised standards or equivalent, as well as those which have been designed without applying the relevant provisions of those standards.

The Notified Body must extract from the manufacturer drawings and, where appropriate, the pressure equipment data sheets and purchaser's technical specifications, all loading information, design and operating conditions which must be taken into account during assessment of pressure equipment.

Acceptance of the design by the Notified Body shall depend on their independent calculations showing compliance with the requisite standards, purchaser's technical specifications, data sheets and drawings.

The Notified Body may, where considered appropriate, make reference to manufacturer's calculations. Where it is requested by the manufacturer or purchaser that manufacturer's design calculations should be endorsed by the Notified Body, these manufacturer's design calculations shall be checked in detail.

Any discrepancies found during the appraisal of the technical documentation, are to be advised to the manufacturer to allow him to take necessary corrective action. The amendments are reviewed to ensure compliance with the design requirements.

If the design proposed by the manufacturer has not been prepared in accordance with the design rules of the standards, then the manufacturer shall supply to the Notified Body all the necessary information in support of this design approach. This can consist of analyses, proof test data, operating experience or any other data the manufacturer considers relevant support of this method of design.

In all cases such alternate methods of design shall provide pressure equipment which will be as safe as those provided by the rules of the standards.

Once the design calculations and the technical documentation are complete to the satisfaction of the Notified Body, an EC Design-Examination Certificate will be issued by the Notified Body, which shall indicate compliance with relevant harmonised standards or equivalent and purchaser's technical specifications.

Where the requirements of purchaser's technical specifications are greater than requirement of the Directive, an LR Certificate will be issued in addition to the EC Design-Examination Certificate which only shows compliance with the requirements of the Directive.

Appendix B – Case Study and the use of Standards

This section will consider a case study and the use of standards for an assessment to be made of the conformity of safety requirements of the pressure equipment with the requirements of the Directive which apply to it. Discussions and comparisons are drawn in the assessment of the essential safety requirements of a vessel using the draft proposal of CEN/TC 54 (the proposed harmonised standard) and that of BS 5500 in meeting the essential safety requirements of the Directive.

A Test Separator is used for this case study and Appendix C summarises the information which is extracted from the manufacturer's general arrangement drawings and detail drawings. This Test Separator had been designed, tested and manufactured to BS 5500 Code Category 1.

B.1 Classification of Pressure Equipment

The maximum allowable pressure (PS) and volume (V) of the Test Separator is 142 barg and 4380 litres respectively. The Test Separator contains hydrocarbon gas, condensate and water, which cannot be classified as group 1 fluid as defined in Article 9, Section 2.1 of the Directive. Therefore, the fluids within the Test Separator are classified as group 2.

B.2 Conformity Assessment Table

The volume is greater than 1 litre (L) and a product of PS and V is greater than 50 bar.L, therefore, Annex II, Table 2 of the Directive is used in accordance with Article 3, Section 1.1 (a), second indent of the Directive. The pressure and volume of the Test Separator has been plotted in the Annex II, Table 2 of the Directive as shown in Table B.1 of this Paper. From the table, the equipment is classified as Category IV and Module G has been chosen for the conformity assessment.

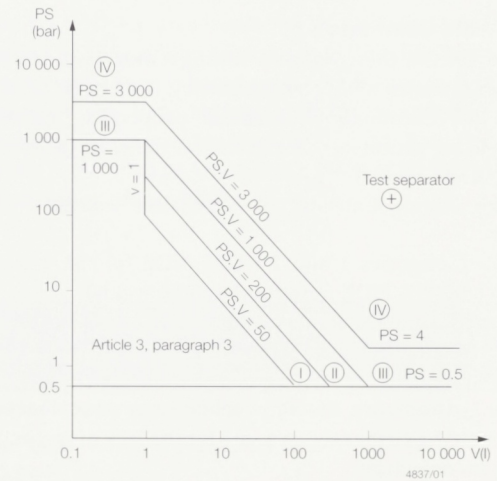


Table B.1 Conformity Assessment Table for Test Separator

B.3 Presumption of conformity and standards

According to Article 3, Section 1 of the Directive, this equipment must satisfy the essential requirements set out in Annex 1 of the Directive, i.e., 'Essential Safety Requirements'. Article 5 of the Directive states that pressure equipment which conform to the harmonised standards shall be presumed to conform to the essential safety requirements of the Directive. The following amendment to the Directive was recently proposed to the council (Ref. 1) :

'When harmonised standards are not followed, the pressure equipment shall be designed, manufactured and inspected with a safety level equivalent to the application of the harmonised standard'.

Therefore, any approach using equivalent standard which satisfies the essential safety requirements of the Directive will be permissible.

B.4 Technical Requirements and Essential Safety Requirements

B.4.1 General

According to Annex 1 of the Directive, 'Essential Safety Requirements', this Test Separator must be designed, manufactured and checked to prevent danger, including danger where potential for misuse is known or is clearly foreseeable. The design methods of pressure parts and other loading aspects of the Test Separator are based on 'design by formula' from the standards.

B.4.2 Design

The Test Separator must be designed for following loadings:

- Internal design pressure of 142 barg and external design pressure of -1.013 barg (Full Vacuum).
- Design temperature of - 50 / 75°C.
- External blast load of 10 kN/m2 and wind load of 55.9 m/s.
- Mechanical loads on nozzles (See Appendix C).
- Hydrostatic test condition.
- Corrosion due to content and erosion due to sand particles.

B.4.3 Weld Joint Factor

In CEN/TC 54, there are five Testing Categories, (Testing Categories relates to the joint geometry, level of NDE (non-destructive examination), material properties, thickness and welding processes). For example, the joint factors for carbon steels are:

- 1.0 for Testing Category of Alternative Routine (100% NDE);
- 1.0 for Categories 1 and 2 (100% NDE for longitudinal seam and 25% NDE for cirumferential welds);
- 0.85 for Testing Categories 3 (10% NDE), and
- 0.7 for Testing Category 4 (no NDE).

For the last category, the allowable design stress is multiplied by 0.9 to further compensate for the lack of inspection during manufacture.

In BS 5500 there are three category of constructions, namely category 1 (100% NDE), category 2 (10 % NDE) or category 3 (no NDE) which have different restrictions related to thickness and materials. Also category 3 has special design stress level restrictions. There is no weld joint factor in BS 5500 equation, for all three categories have a joint factor of 1. However, the lower stresses specified for category 3 imply the use of a weld factor.

For the thickness of the Test Separator, 100% NDE is required and thus the weld joint factor to be used under CEN/TC 54 is 1.0.

B.4.4 Allowable Design Stresses and Cylindrical Shell

For carbon and low alloy steels, the allowable design stress of CEN/TC 54 is based on the lesser of yield/1.5 and UTS/2.4 for the normal route and the lesser of yield/1.5 and UTS/1.875 for the alternative route. (UTS is the ultimate tensile strength at room temperature and yield is 0.2% proof strength at design temperature). The alternative route is required to meet the requirements as given in Annex A of the Standard, with a number of restrictions and additional requirements on materials, impact properties and NDE to be met.

In BS 5500, the allowable design stresses are tabulated in Section 2 of the Standard for standard BS materials or Enquiry Case BS 5500/91 for some ASME materials. The basis of the allowable design stresses is given in BS 5500 Appendix K and is based on the lesser of yield/1.5 and UTS/2.35 for carbon, carbon maganese and low alloy steels.

The allowable design stresses for both standards of the shell materials for the Test Separator are shown on Table B.2.

The minimum shell thickness calculated from both standards is shown on Table B.3.

It is shown that CEN/TC 54 and BS 5500 required same shell thickness as both standards use the same equation and allowable design stress. It is noted that the alternative route of CEN/TC 54 does not give any advantage for this case; the yield stress controls. The proposed shell thickness of 45mm plus 3mm cladding is considered to be acceptable to both standards.

It is noted that the above comparison is based on the weld joint factor of 1 for 100% NDE, and for other cases if partial or no NDE is applied, the thickness required by CEN/TC 54 will be greater than BS 5500.

B.4.5 Dished Ends

According to Ref. 4, the design of dished ends under internal pressure of CEN/TC 54 is mainly based on Kalnins and Updike's data (Ref. 5) but with a modification factor. Their data are based on finite element studies, which used elastic/plastic theory for taking account of large deflections.

BS 5500 has its own unique method for the design of dished ends, though it is related to that in ISO/DIS 2694 according to Ref. 4.

For the Test Separator's Korbbogen type of dished end, the required thicknesses for both standards are shown on Table B.4.

Table B.2
UTS, Yield and Design Stresses of BS 1501-224-490E-LT50 Material

				BS 5500	CEN/TC 54	CEN/TC 54 (Alt. Route)
Material	UTS	Yield (Atm)	Yield (75 Deg C)	Design Stress	Design Stress	Design Stress
BS1501-224-490B-LT50	490 N/mm2	305	292.75	195.2	195.2	195.2

Table B.3
Minimum Required Shell Thickness for Various Standards

Standards	Minimum Required Shell Thickness (mm)	Proposed Shell Thickness (mm)
BS 5500	40 + 3mm Cladding	45 + 3mm Cladding
CEN/TC 54 (Normal Route)	40 + 3mm Cladding	45 + 3mm Cladding
CEN/TC 54 (Alt. Route)	40 + 3mm Cladding	Not Applicable

Table B.4
Minimum Required Thickness for Korbbogen Type of Dished End for Test Separator

	Minimum Required Thickness (mm)			Proposed Thickness (mm)
Standards	Straight Flange	Crown Ends	Knuckle	
BS 5500	40 + 3mm Cladding	34.2 + 3mm Cladding	36.9 + 3mm Cladding	45 + 3mm Cladding
CEN/TC 54	40 + 3mm Cladding	34.1 + 3mm Cladding	34.1 + 3mm Cladding	45 + 3mm Cladding

The required thickness for the crown ends to CEN/TC 54 is slightly greater than that required by BS 5500 by 0.1mm. The thickness for the crown ends for both standards are based on the equation for a spherical shell. The equations in both standards are similar.

The required thickness of the knuckle is lower using the CEN/TC 54 method. In CEN/TC 54, the thickness of the knuckle is the greatest of the following:

(a) minimum thickness of the crown end;
(b) minimum thickness of knuckle to avoid axisymmetric yielding;
(c) minimum thickness of knuckle to avoid plastic buckling.

In the case of the Test Separator, thickness (a), 34.1mm, applies. In BS 5500, the knuckle thickness is determined from the design chart, which in this case is 36.9mm.

However, the required thickness for the straight flange is the same for both standards which is based on the shell equation. The proposed head thickness of 45mm plus 3mm cladding is considered to be satisfactory to both standards.

B.4.6 External Pressure

The method used for the CEN/TC 54 is based on the BS 5500 method with some changes. The major changes are:

(a) The traditional "sf" factor (material factor x design stress) has been replaced by yield stress at design temperature for carbon steel and low alloys in the CEN/TC 54 method.
(b) The equations have been rewritten and the graphs have been redrawn so that the overall factor of safety of 1.5 is clearly shown.

For this Test Separator, the maximum allowable external pressure of shell and head for both standards are shown on Table B.5. It is noted that the CEN/TC 54 method has slightly higher maximum allowable external pressure. This is due to CEN/TC 54 using a factor of safety of 1.5 whereas BS 5500 uses a material factor of 1.4. The proposed shell and heads are suitable for full vacuum to both standards.

B.4.7 Reinforcement of Nozzles

The CEN/TC 54 for reinforcement of nozzles and openings follows continental practice by using a pressure area force balance method. The Appendix F method of BS 5500 is an area replacement method, but cannot be compared with the continental methods since the distance away from the branch/shell junction available for reinforcement is completely different. The method in Section 3 of BS 5500 was based on limiting stresses to values which had been shown by the methods available at the time to give reasonable margins against gross deformation and failure by ratcheting, with the emphasis on the latter. While the area approach may appear strange to users of BS 5500 Section 3.5.4, the concept is recognised in BS 5500 in the rules for groups of openings and for the concentration of reinforcing material closer to the opening.

Table B.6 shows the amount of reinforcement provided for a selection of nozzles for the two standards. It can be seen that for grouped nozzles, once nozzle thickness/shell thickness (t/T) of any one of the nozzles exceeds unity, then the area methods used by CEN/TC 54 become over optimistic. Both standards give similar assessments.

The method of area replacement specified in BS 5500, Appendix F, is subject to a proposed modification (Ref. 6). The method given is based on that contained in BS EN 286-1 (pressure area force balance method), modified slightly to align with proposals for the CEN/TC 54. This amendment has been included in Amendment No. 4 of BS 5500 and effective from 1 October 1996.

Table B.5
Maximum Allowable External Pressure (barg) for Test Separator

Standards	Shell	Head
BS 5500	104	96.9
CEN/TC 54	108.7	103.7

Table B.6
Reinforcement of Nozzles for Test Separator

Location	Nozzle Mark	Nozzle Thk/Shell Thk	BS5500 (Sect. 3) (%)	CEN/TC 54 (Sect. 9) (%)
Head	N2	1.2	105	116
Head	N2 and P2	1.2 and 0.51	117	126
Head	N4A	0.91	136	124
Head	N4A & L4B	0.91 and 0.66	127	128
Shell	N1	1.33	104	114
Shell	H2 and L4A	1.2 and 0.48	143	152
Shell	H2 and F1	1.2 and 0.51	212	225
Shell	P4 and L2A	0.51 and 0.48	124	127

B.4.8 Body Flange

The CEN/TC 54 Taylor Forge flange design method is based on the version now in BS 5500, but with a reduction in design stress by a factor 0.75 for diameters greater than 2000mm and an increase in bolt stress from yield/4 to yield/3. The CEN/TC 54 also contains an alternative method developed and used in East Germany that takes account of real flange behaviour and aims to prevent leakage as well as limit stresses.

For this Test Separator (diameter is less than 2000mm), the Body Flange stress ratios based on the Taylor Forge Method as calculated by these two standards are shown on Table B.7. The design stresses of bolting are taken from Table 3.8.1.4 for the BS 5500 case and derived from BS 4882 for the CEN/TC 54 case. The stresses of the Body Flange of the Test Separator are similar for both standards. The proposed body flange is satisfactory for both standards.

A recent development (Ref. 6) of BS 5500 is that the design stress of bolts will follow the same approach as the proposals for the CEN/TC 54. This draft amendment will be included in the Amendment of BS 5500.

B.4.9 Nozzle Flanges

At present, there is no draft European Standard for Flanges. The most commonly used flange standard is ASME/ANSI B16.5. Based on the design pressure and design temperature of 142 barg and 75°C, flange rating of 900 psig is acceptable and thus satisfied the requirements of the Directive.

B.4.10 Mechanical loads due to Nozzles

Methods of calculating stresses from local loads on vessels has not been included in the draft proposal CEN/TC 54. The mechanical loads on the nozzles of the Test Separator has been checked in accordance with Appendix G of BS 5500. The results are shown on Table B.8 and all the nozzle loads are considered to be acceptable and thus satisfy the requirements of the Directive.

B.4.11 Skirt Support and Holding Down Bolts

Both the draft proposal CEN/TC 54 and BS 5500 do not contain the design methods for skirt support and holding down bolts. The commonly used design method is given in Ref. 7. The worst case is due to the blast load, the calculations show that the skirt support and holding down bolts are suitable to withstand the blast load. The results are shown on Table B.9 and can be seen to satisfy the requirements of the Directive.

Table B.7
Maximum Stress Ratios of Body Flange for Test Separator

Standards	Operating (%)	Bolting-Up (%)
BS 5500	96.9	86.2
CEN/TC 54	96.9	90.9

Table B.8
Maximum Stress Ratios due to Nozzle Loads for Test Separator

Location	Nozzle Mark	BS 5500 App. G (%)
Head	N2	81.6
Head	P1	61.5
Head	N4A	68.8
Shell	F1	82
Shell	N1	95

Table B.9
Stresses due to Blast Load for Test Separator

Stresses Due to Blast Load	N/mm2
Maximum combined stress in the shell in longitudinal direction	98
Maximum compressive stress in the shell at the bottom of tangent line	11
Maximum longitudinal compressive stress of the skirt	25
Maximum stress in the skirt-to-head weld	46
Maximum stress at a section of skirt through the access opening	38
Maximum bending stress in the base ring	74
Maximum stress in holding down bolts	77

B.4.12 Hydrostatic Test Pressure

For the Test Separator, the hydrostatic test pressure of the draft proposal CEN/TC 54 shall be not less than that determined by the following:

$$pt = 1.25 \times p \times (fa/ft)$$

or

$$pt = 1.43 \times p$$

whichever is higher.

For BS 5500, the hydrostatic test pressure shall be not less than the following:

$$pt = 1.25 \times p \times (fa/ft) \times (t/(t-c))$$

where

pt is the test pressure;

p is the design pressure;

fa is the allowable design stress at test temperature;

ft is the allowable design stress at design temperature;

t is the nominal thickness of the section under consideration;

c is the corrosion allowance.

The maximum permissible membrane stress under hydrostatic test for CE/TC 54 is (yield/1.05) which is slightly higher than permitted by BS 5500 (where 0.9 times yield is used).

Table B.10 shows the hydrostatic test pressure calculated for these two standards, it is noted that the CE/TC 54 method requires a slightly higher hydrostatic test pressure. However, the test pressure determined by BS 5500 should be adequate in satisfying the requirements of the Directive.

Table B.10
Hydrostatic Test Pressure for Test Separator

Standards	Hydrostatic Test Pressure (barg)
BS 5500	197.2
CEN/TC 54	203.1

B.4.13 Means of Examination

Access for examination are provided by two head holes, one inspection hole and the body flanges. These are acceptable for both standards.

B.4.14 Protection and Safety Accessories

Nozzle P1 will be fitted with Pressure Safety Valve (PSV) to prevent the maximum allowable pressure being exceeded permanently. This relieving pressure of PSV is kept to 10% above the maximum allowable pressure in accordance with BS 5500 or CEN/TC 54. Level transmitters are also fitted on nozzle L1A/B and L3A/B for high-high and low-low level for condensate and interface respectively. The level settings for these transmitters contain operating, alarm and shutdown for all design cases. Temperature transmitters are also fitted into the inlet and outlet nozzles' pipework. The Test Separator has sand jetting internals to assist sand removal when the vessel is in an off-line mode without requiring man-entry. All these protection devices should satisfy the requirements of the Directive.

B.4.15 Materials for Pressure Parts

Materials used for the manufacture of the Test Separator are suitable for the application during the scheduled lifetime. Cladding of 3mm Type 316L is used for shell, heads, flanges nozzle and girth flange of Test Separator to give adequate corrosion resistance.

At present, the material specifications for this Test Separator has not been listed in harmonised standards or European Approval. Material specifications for this Test Separator must be subject to a formal material appraisal. This appraisal must be performed by the Notified Body in charge of conformity assessment procedures to fulfil the requirements of the Directive.

The manufacturer must take appropriate measures to ensure that the material used conforms with the required specification, in particular by obtaining:
- Material manufacturers' documentation affirming compliance with a specification for all materials, including joining materials.
- A certificate of specific product control for the main pressure bearing parts , excepting joining materials.

The Test Separator's materials have impact test values of above 50 Joules at minus 50°C and thus satisfy the impact test requirements of both standards.

The Test Separator's materials have sufficient ductility, i.e., the elongation after rupture of these materials are greater than 14% and thus satisfy the requirements of the Directive.

B.4.16 Manufacturing

B.4.16.1 Joining

As this Test Separator is category IV equipment, manufacturing procedures and personnel must be approved by a competent third party which may be chosen by the manufacturer. This third party may be a Notified Body or a recognised third-party organisation. The third party must perform examinations and tests as set out in the standards as specified in the following paragraphs.

"The manufacturer shall compile welding procedure specifications (WPS) in accordance with BS EN 288-2 for each joint or family of joints, except as modified by the requirements of BS 5500 or CEN/TC 54 as appropriate.

Welding procedure specification to be used shall be approved by welding procedure tests in accordance with BS EN 288-3 for metallic materials, except as modified by the requirements of BS 5500 or CEN/TC 54 as appropriate.

Qualification of welders and welding operators shall be approved to BS EN 287-1 for the welding of steel."

CEN/TC 54 and BS 5500 have the similar approach of using the above standards for welding.

There are no European Standards for welding procedure specification and qualification for corrosion resistant weld metal overlay, Sections QW-381 and QW-453 of ASME IX is commonly used.

Production control test plates have been specified for the main shell longitudinal and circumferential welds for the Test Separator. These are required by both standards.

B.4.16.2 Non-Destructive Examination

The overall development of European Standards of NDE is still relatively slow (Ref. 10). For CEN/TC 54, personnel performing and evaluating non-destructive examinations shall be qualified and certified in accordance with BS EN 473. Non-destructive testing personnel shall hold an appropriate certificate of competence (e.g. Personnel Certification in Non-Destructive Testing (PCN)) which is recognised by the Notified Body. BS 5500 has a similar approach.

As the Test Separator is category IV equipment, the NDE personnel must be approved by a recognised third-party organisation.

On the whole, the NDE requirements in the CEN/TC 54 are not significantly different from those in both BS 5500 and ASME, however, there are differences. CEN/TC 54 is more detailed in part because of the number of different Testing Categories. There are five Testing Categories in CEN/TC 54 against three categories in BS 5500. In the CEN/TC 54, however, testing categories are relevant to individually welded joints and not the whole vessel as in the case of BS 5500. In this respect, it is similar to ASME Section VIII Division 1 where the levels of NDE can be full, partial, spot or none, and on a single vessel be a combination of all providing there are not overriding requirements in respect of vessel contents or material thicknesses. There are, however, additional requirements in CEN/TC 54 for testing category 'Alternative Route' and testing catedory 4 which must be used for the entire vessel.

In CEN/TC 54 the test categories are further split for material grouping with material more sensitive to cracking receiving greater attention. One aspect which is new to both BS and ASME practice relates to relaxation in levels of NDE following satisfactory experience over a period of the time. This is very much a German philosophy although in CEN/TC 54 it is limited to testing category 2 only.

For this Test Separator, full NDE is required. The extent of NDE is specified on Section C.5 of Appendix C of this Paper. The extent of NDE is acceptable for both standards.

B.4.16.3 Heat Treatment

The proposed CEN/TC 54 and the alternative requirements of BS 5500 for post-weld heat treatment (PWHT) are similar. However, the holding time suggested is substantially less than the normal requirements of BS 5500. The proposal is largely based on the experience of European practice and Germany in particular. According to BS 5500, the use of the alternative requirements is likely to result in residual stresses higher than those resulting from the use of normal requirement of BS 5500, with consequent effect on, for example, any defect analysis or stress corrosion.

The Test Separator is a cladded vessel, but the post-weld heat treatment is specified in accordance with the base material. The holding time and temperature for PWHT should be 112.5 minutes at 580-620 °C which are based on the normal requirements of BS 5500. These, are again within the limits acceptable by the Directive.

B.4.16.4 Material Traceability

Both standards require that the manufacturer must establish and maintain suitable procedures for identifying the material making up the components of the Test Separator which contribute to pressure resistance by suitable means from receipt of steel, through production, and up to the final test of the manufactured Test Separator. This is a requirement of the Directive.

B.4.17 Final Assessment

B.4.17.1 Final Inspection

Both CEN/TC 54 and BS 5500 require the Test Separator to undergo a final visual inspection and examination of the accompanying documents, which is in compliance with the requirements of the Directive.

B.4.17.2 Proof Pressure Test

A proof pressure test, normally a hydrostatic test, must be carried out at a pressure at least equal, where appropriate, to the value specified in Paragraph B.4.12 above. This proof pressure test is required by both standards.

B.5 Conformity Assessment Procedures

Module G of the Directive has been chosen for a conformity assessment for the Test Separator. The technical documentation required for Module G for the Test Separator is summarised in Table B.1. The responsibilities for approving the design and controlling the various stages of manufacture and inspection are given in Table B.11. These are applicable for both standards in order to comply the requirements of Annex III of the Directive.

B.6 Conclusions

From this case study, it can be concluded that there is no significant difference in the results of the verifications of the essential safety requirements under BS 5500 and CEN/TC 54 standard for this Test Separator. This, therefore, supports the use of BS 5500 in the design and manufacture of pressure vessels with a safety level equivalent to the application of the harmonised standard and thus satisfies the essential safety requirements of the Directive.

Currently in the UK, BS 5500 is referenced in Pressure System Regulations but its use is not mandatory. One of the recent developments of BS 5500 (Ref. 11) is the promotion of the concept of retaining it as a PD (Published Document) instead of a BS, hence, extending its potential life (i.e., PD 5500). Another recent development of BS 5500 (Ref. 6) is to adopt a similar approach to CEN/TC 54 in some of the

design methods, hence bringing the standard further in line with the requirements of the harmonised standard.

It is worth mentioning that French Code CODAP and German Code AD Merkblätter will not be viewed as national standards, but will be treated as codes of practice and hence will not be superseded after the publication of CEN/TC 54. Countries may continue to use their codes of practice to satisfy the essential safety requirements of the Directive.

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Table B.11
Conformity Assessment Table for Test Separator

Area of Activity	Inspection Operation	Module G
Qualification		
Qualification of Manufacturer	Apply to single Notified Body for Verification	MFR
	Assessment of vessel manufacturer's capability	MFR
	Assessment of pressure part material supplier's capability	MFR
Design and General Documentation		
Design data/calculation	Verify that design data/calculations conform to: technical data for manufacture the requirements of the standard used	NB
Manufacturing drawings	Verify that drawing information conforms to: the results of the design documents technical data for manufacture the requirements of the standard used	NB
Purchase specifications	Verify that material and component specifications conform to: technical data for manufacture manufacturing drawing the requirements of the standard used	NB
Specifications for subcontracted parts	Verify that specifications for subcontracted parts conform to: technical data for manufacture manufacturing drawing the requirements of the standard used	MFR or NB
Material		
Acceptance of material at material manufacturers works, or stockists	Witness the taking of samples for the production of test specimens	NB
	Check that results of specimen tests conform to purchase specification	NB
	Examine material to verify conformance with the purchase specification	NB
NDE of Material	Verify operators qualifications validity	NB
	Verification of existence of NDE reports and check conformance of results to purchase specification	NB
Material Certificates	Verify that certificate information and results conform to the design specification	NB
Welding consumable	Verify that consumable to be in accordance with the design specification	NB
Material identification	Identify material with material certificates and check marking at manufacturer's work	NB
Transfer of identification marks	Examination of the procedure drawn up by the manufacturer for the transfer of the marks	NB
	Transfer of identification marks	NB
Acceptance of subcontracted parts	The manufacturer shall specify the minimum required inspection operations to be carried out at the subcontractors works	NB
Fabrication and welding		
Welding specifications	Verify that appropriate welding specifications are available and their contents are compatible with welding procedure qualifications	NB
Welding procedures approvals	Verify that welding procedures approved by a notified body are available for the materials and field of welding applications	NB
Welding approval	Verify that welder approvals, approved by a notified body, are available and valid	NB
Responsibility Key: MFR = Manufacturer, NB = Notified Body		

Table B.11 (continued) Conformity Assessment Table for Test Separator		
Area of Activity	Inspection Operation	Module G
Fabrication and welding (continued)		
Forming procedures	Verify that forming procedures are available, where applicable, and their contents are appropriate to the product to be formed	NB
Weld preparation	Examine material cut edges and heat affected zones	MFR
Weld seam set up	Examine set up of seams for welding, including dimensional check	MFR or NB
Weld root	Examine second side of weld preparation after first side of weld is completed and root cleaned	MFR
Visual examination of welds	Visual examination of completed welds for penetration, fusion or profile defects, prior to any PWHT	MFR or NB
Production test plates	Witness removal and marking of production test plates	NB
	Verify that any PWHT on production test plates independent of the vessel complies with the specific heat treatment applied to the vessel	NB
	Examine NDE reports on production test plates	NB
	Identification and marking of test specimens taken from production test plates for mechanical tests	NB
	Witnessing of mechanical tests	NB
	Verify that test information and results contained in manufacturer's report conform to the requirements of standard used	NB
Post weld heat treatment (PWHT)		
PWHT procedures	Verify PWHT procedures conform to the standard used	NB
PWHT records	Verify that temperature / time recordings conform to the requirements of the standard used	NB
NDE of welds		
NDE procedures	Verify that appropriate NDE procedures are available and check qualification of originator	NB
NDE operator approvals	Verify the validity of the NDE operator approvals	NB
NDE operation	Verify radiographic examination results and check conformance to the acceptance criteria	NB
	Attendance at NDE other than radiographic examination	MFR or NB
NDE reports	Verify that information and results conform to the acceptance criteria	NB
Final inspection and marking		
Pre-hydrostatic pressure test inspection	Dimensional checking, visual examination and identification of accessible parts after component completion, prior to hydrostatic pressure test and application of any covering at manufacturer's work	NB
Hydrostatic pressure test	Witness final hydrostatic pressure test at manufacturer's work	NB
Post hydrostatic pressure test inspection	Visual examination on completion of hydrostatic pressure test	NB
	Check marking of nameplate	NB
Safety devices	Check provision for safety equipment if applicable	NB
CE mark	Affix CE mark	MFR
NB identification number	Affix identification number	NB
Declaration of conformity	Issue declaration of conformity	MFR
Certificate of conformity	Issue certificate of conformity	NB
Manufacturer's data dossier	Review data dossier for completeness	NB
	Keep documentation for 10 years	MFR
Responsibility Key: MFR = Manufacturer, NB = Notified Body		

Appendix C – Information and Data for Test Separator

This Appendix summarises the information which are extracted from the manufacturer's general arrangement drawings and detail drawings of Test Separator.

C.1 Design and Operating Data

Design Code: BS 5500: 1991

Category: 1

Operating Temperature: 50°C

Operating Pressure: 10 to 136 barg

Design Temperature: 50/75°C

Design Pressure: 142 barg and Full Vacuum

Corrosion Allowance: 0mm (3mm Cladding)

C.2 External Loads

External Blast Load: $10kN/m^2$

Wind Load: 55.9m/s

C.3 Weight and Volume

Dry Weight: 16230Kg

Operating Weight: 18573Kg

Hydrotest Weight: 20960Kg

Weight of Internals: 500Kg

Operating Volume: $2.35m^3$

Total Volume: $4.38m^3$

C.4 Materials

Shell, Heads, Base Ring and Chairs, Skirt, Lifting Lugs, Earthing Lugs, Brackets/Supports, Pipe Clips: BS 1501-224-490B-LT50

Cladding: 3mm Typ 316L

Forged Nozzles, Forged Flanges and Blind Flanges: BS1503-224-490E-LT50

Bolts for External Flanges: BS 4882 Gr. L7

Nuts for External Flanges: BS 4882 Gr. 7

Bolts for Internal Flanges: ASTM A320 M88 B8M

Nuts for Internal Flanges: ASTM A194 M88A 8M

Foundation Bolting: BS 3692 Class 8.8

Removal and Fixed Internals: UNS S31603/AISI 316L

Nameplate: UNS S31603

C.5 Fabrication/Inspection Requirements

All carbon steel forgings shall be subject to 100% ultrasonic inspection and 100% magnetic particle inspection.

All shell and head material shall be subject to 100% ultrasonic inspection.

Integrally clad plate and linings applies by overlay weld depositing shall be ultrasonically tested to check the quality of the bond in accordance with the requirement of ASTM A 578, acceptable level S6 or equivalent.

Clad plate formed into dished ends shall be ultrasonically tested for soundness after forming.

All welds shall be subject to visual inspection.

All welds shall be subject to 100% magnetic particle inspection for carbon steels and 100% dye penetrant inspection for non-ferritic materials.

All butt welds shall be subject to 100% radiography test.

For nozzle to shell welds and lifting lugs, 100% ultrasonic testing shall be performed. Ambiguous imperfections in butt welds found by radiographic testing shall in addition be ultrasonic tested. Acceptance criteria shall be in accordance with Enquiry Case 5500/92.

The final NDE shall be carried out after completion of post-weld heat treatment.

C.6 Notes

1. The Test Separator is to be of the Swirldeck-Mistmat-Schoepentoeter (SMS) type vertical separator. See Figures C.1 to C.4. The SMS separator is designed in accordance with SHELL DEP 31.22.05.11 – GEN (February, 1991) "Gas/Liquid Separators – Type, Selection and design Rules".
2. The Test Separator is to separate the mixed phase feed stream into three phases namely:
   (a) Hydrocarbon Gas;
   (b) Hydrocarbon Condensate;
   (c) Water.
3. The vessel is subject to corrosion because the following compounds are present:

(a) CO2 - 3013 ppm v/v product gas stream.
(b) Salt water from formation water and drilling fluids.
(c) Acids from well operations comprising hydrochloric and hydrofluoric acids. The maximum concentrations are 12 wt% hydrochloric and 3 wt% hydrofluoric.

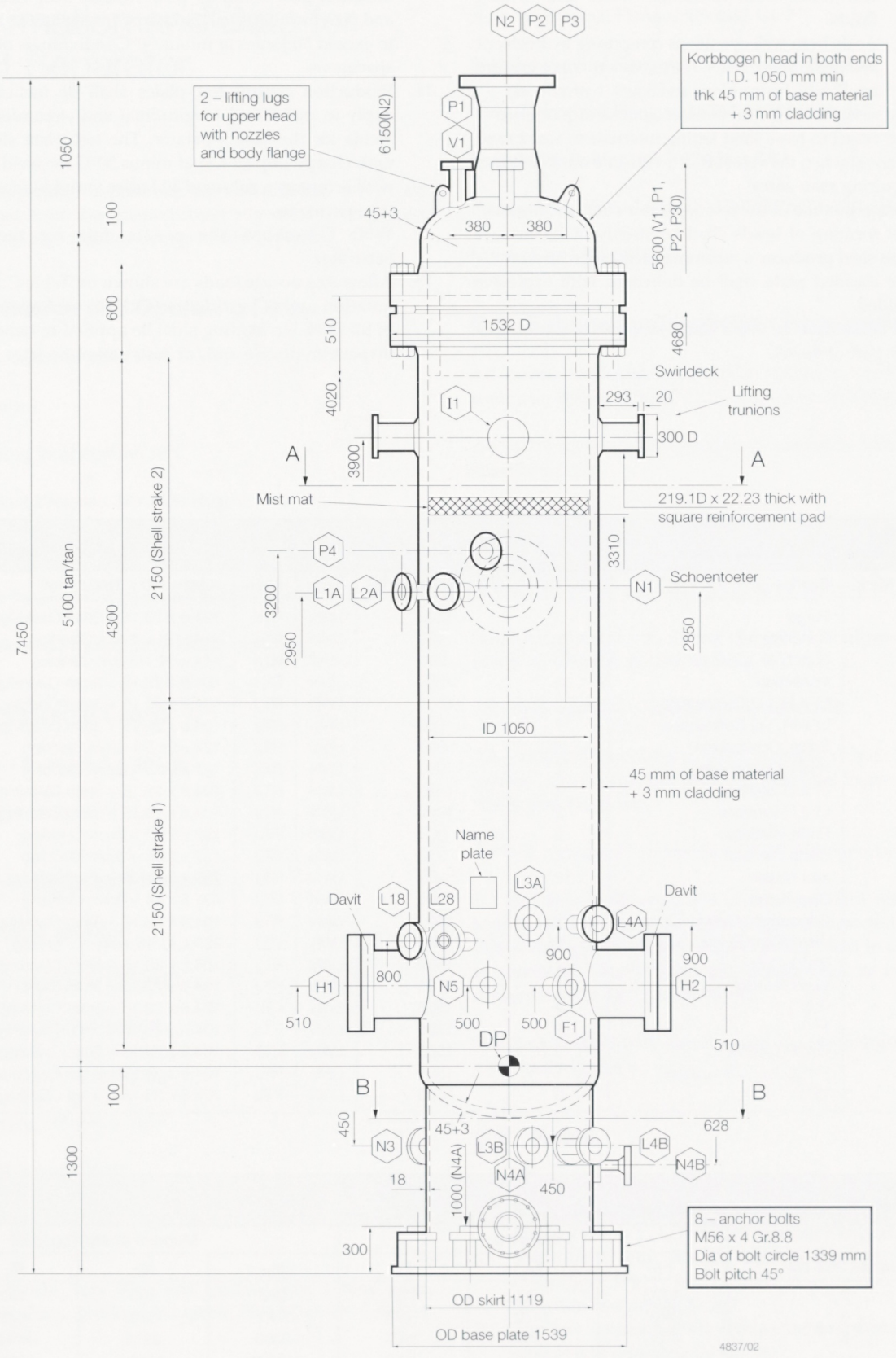
4. The vessel is subject to erosion from sand particles.
5. The vessel to have sand jetting internals to assist sand removal when the vessel is in an off-line mode without requiring man-entry.
6. Design lifetime of the test separator shall be 50 years.
7. Hot forming of heads shall be strictly in accordance with steel producer's recommended procedures.
8. The cladded plate shall be delivered with explosive welded.
9. No credit shall be taken of the strength of cladding of any part of vessel.
10. All carbon steel materials and cladded materials (both included post welding, post welded heat treatment and post forming) shall be charpy impact tested results to exceed 50 Joules at minus 50°C individuals of three specimens.
11. Production control test plates shall be included to apply to main shell longitudinal and circumferential welds for the Test Separator. The test plate shall be with charpy impact test at minus 50°C for weld metal with acceptance values of 50 Joules individual of three test specimens.
12. Table C.1 shows the nozzle data for the Test Separator.
13. Allowable nozzle loads are shown on Table C.2. The notation are as per Figure G.2(21b) of Appendix G of BS 5500. No loading shall be applied to handhole, inspection nozzle and/or instrument nozzles.

Table C.1
Nozzle Data for Test Separator

Nozzle Mark	Service	Size (in)	Flange Rating (#)	Type	Face	Nozzle OD x Thick (mm)
F1	Purge	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
H1	Handhole	12	900	LWN	RTJ	414 x 54 + 3 mm Cladding
H2	Handhole	12	900	LWN	RTJ	414 x 54 + 3 mm Cladding
I1	Inspection	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
L1A	LT (HH, LL) Condensate	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
L1B	LT (HH, LL) Condensate	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
L2A	Bridle, Condensate	3	900	LWN	RTJ	127 x 21.5 + 3mm Cladding
L2B	Bridle, Condensate	3	900	LWN	RTJ	127 x 21.5 + 3mm Cladding
L3A	LT (LL) Interface	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
L3B	LT (LL) Interface	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
L4A	Bridle Interface	3	900	LWN	RTJ	127 x 21.5 + 3mm Cladding
L4B	Bridle Interface	3	900	LWN	RTJ	127 x 21.5 + 3mm Cladding
N1	Inlet Nozzle	12	900	LWN	RTJ	389 x 60 + 3mm Cladding
N2	Gas Outlet	14	900	LWN	RTJ	431.5 x 54 + 3mm Cladding
N3	Condensate Outlet	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
N4A	Water/Sand Outlet	6	900	LWN	RTJ	235 x 41.15 + 3mm Cladding
N4B	Water Outlet	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
N5	Sand Jet Inlet	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
P1	PSV	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
P2	PI	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
P3	PIA (H,LL)/PDI	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
P4	PDI (Lower Connection)	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding
V1	Vent	2	1500	LWN	RTJ	104.8 x 23.15 + 3mm Cladding

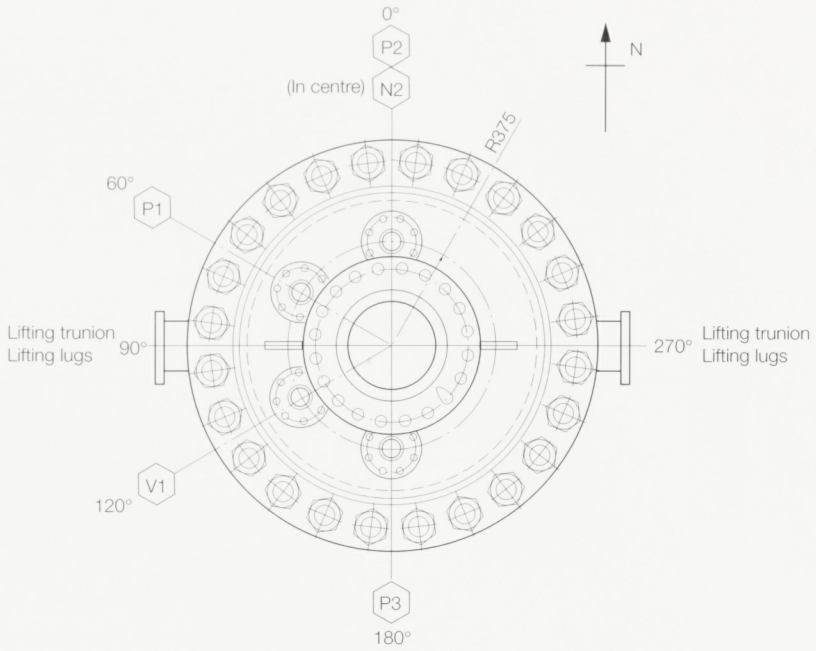
Table C.2
Allowable Nozzle Loads for Test Separator

	Forces (N)			Moment (N-m)		
Nozzle Size (in)	F_R	F_C	F_L	M_R	M_C	M_L
2	1020	720	720	270	190	190
3	2070	1470	1470	810	570	570
6	4950	3500	3500	3700	2615	2615
12	11670	8250	8250	16130	11410	11410
14	12370	8750	8750	18460	13055	13055

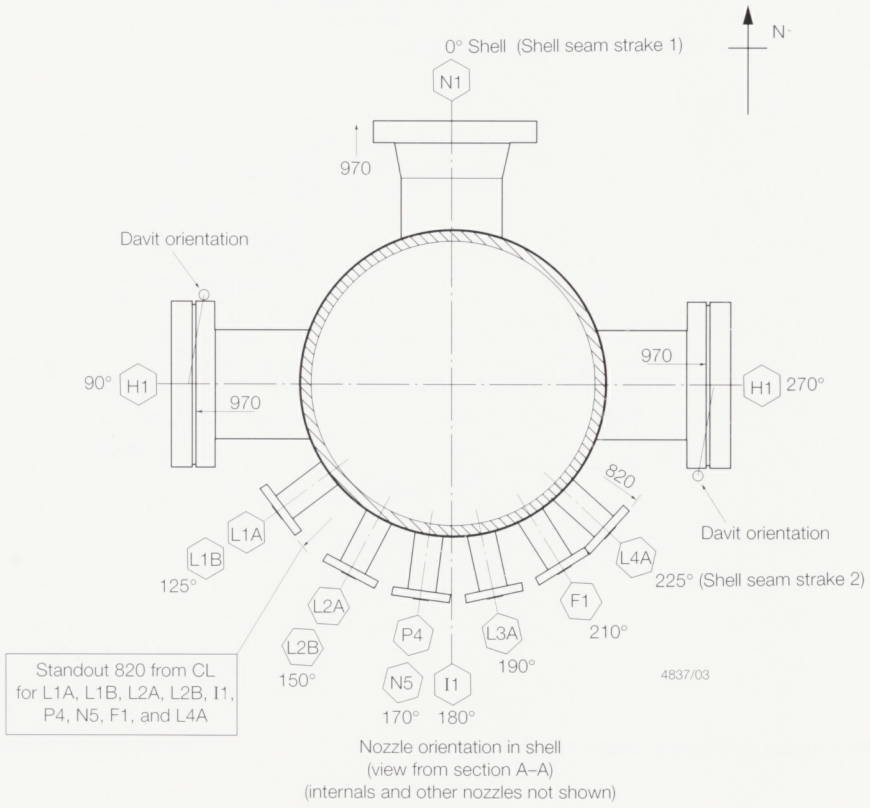


Note : all tail dimensions are from datum point (D.P.)

Figure C.1 Elevation of Test Separator

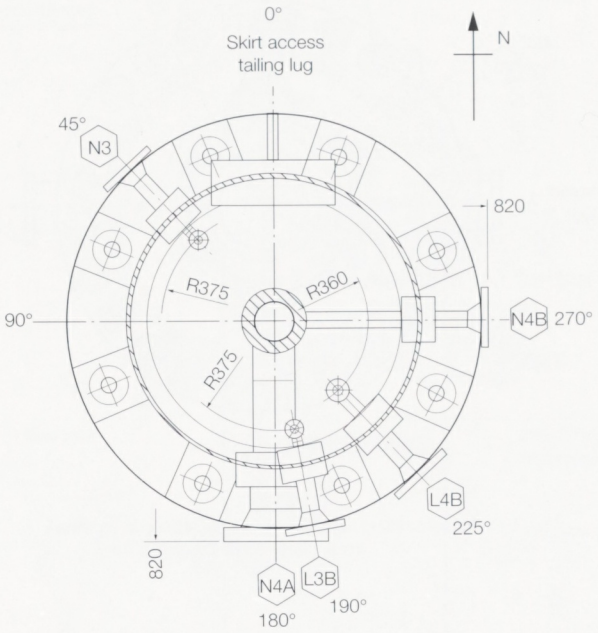


Trunions, lifting lugs and nozzle orientation in top head
(other nozzles not shown)

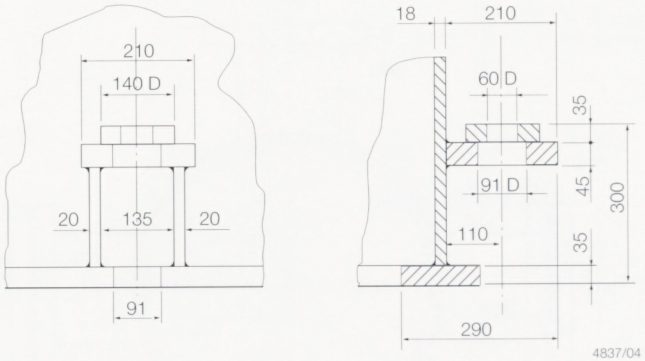


Nozzle orientation in shell
(view from section A–A)
(internals and other nozzles not shown)

Figure C.2 Nozzle Orientation of Test Separator



Nozzle orientation in skirt/bottom head
(View from section B–B)



Anchor Chairs

Figure C.3 Nozzle Orientation and Anchor Chairs of Test Separator

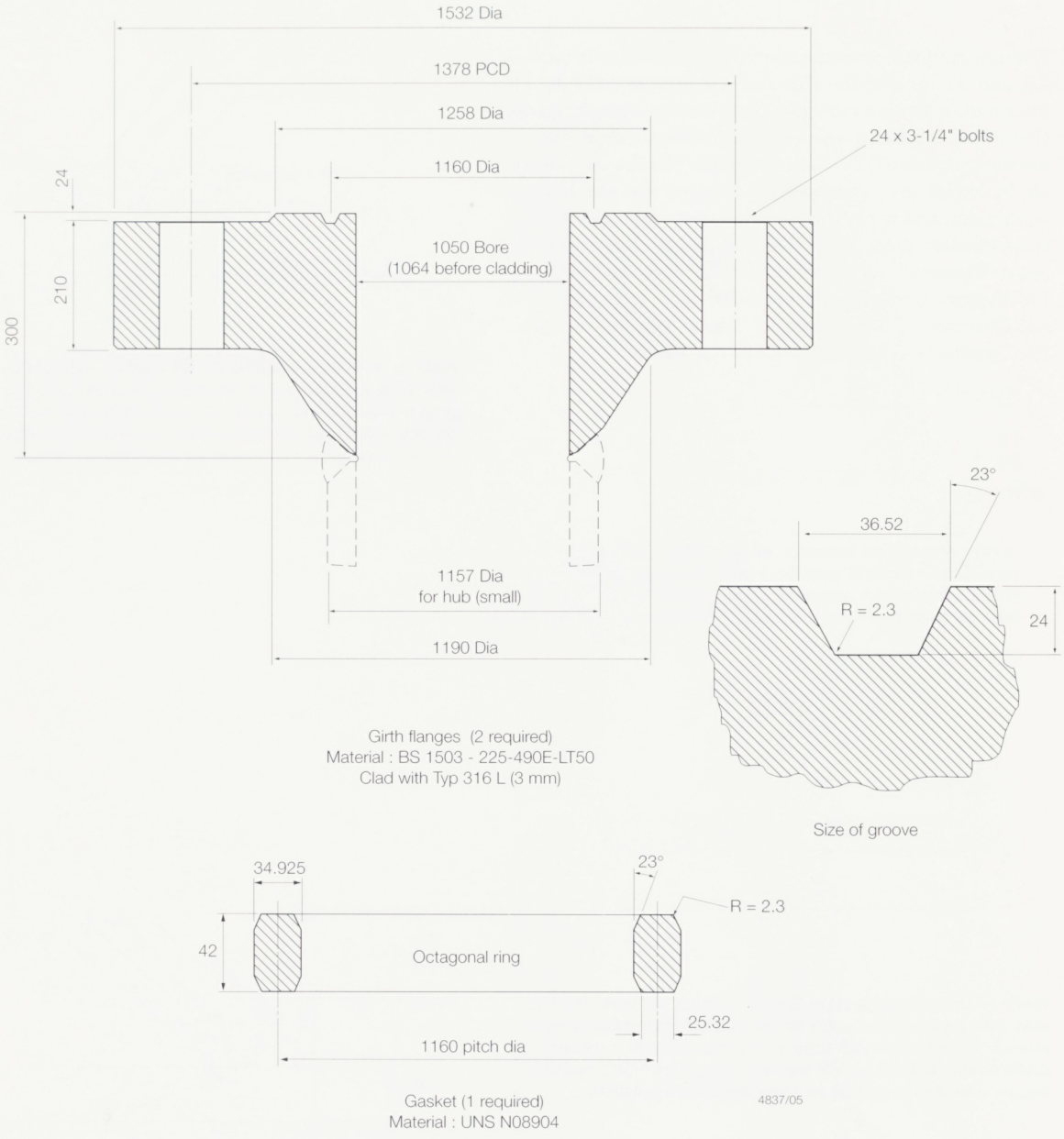


Figure C.4 Body Flange of Test Separator

Appendix D – Conformity Assessment tables

The nine conformity assessment tables referred to in section 4.3, and Annex 2 of the Directive are reproduced here for information. In each table, the maximum working pressure (PS) in bar is plotted against either volume (V) in litre, or nominal pipe size (DN) as appropriate. The Roman numerals in circles give the relevant category for the item of equipment, and hence dictates the selection(s) of conformity assessment modules available to the manufacturer. For items of pressure equipment that fall below the thresholds for category I, the tables refer to Article 3, paragraph 3 of the Directive, which relates to "sound engineering practice", as discussed in section 4.6 of this Paper.

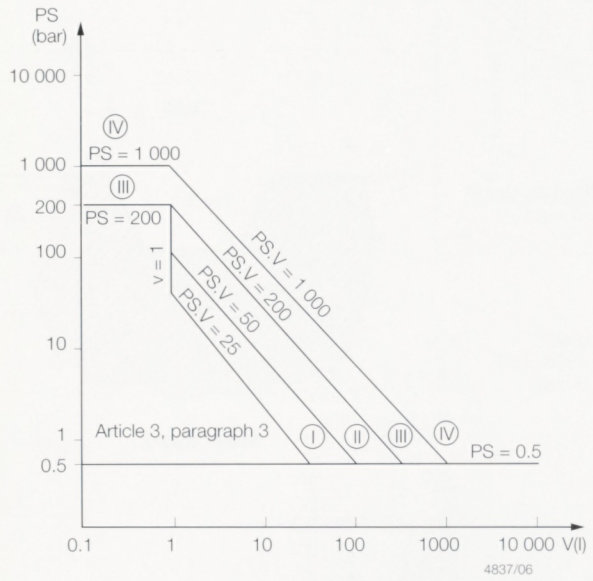


Table 1: Vessels containing Group 1 gases, vapours and liquids with a vapour pressure at the maximum working temperature of greater than 0.5 barg above atmospheric pressure. Additionally, vessels which fall into categories I or II containing an unstable gas must be classified in category III.

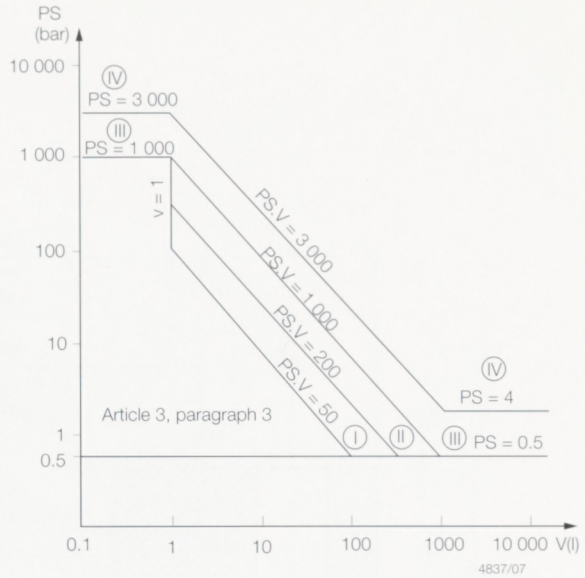


Table 2: Vessels containing Group 2 gases, vapours and liquids with a vapour pressure at the maximum working temperature of greater than 0.5 barg above atmospheric pressure. Additionally, portable extinguishers and bottles for breathing equipment which fall into categories I or II must be classified in category III.

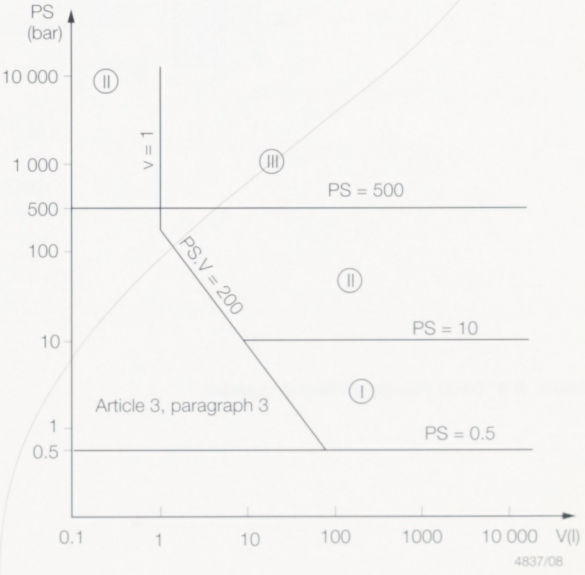


Table 3: Vessels containing Group 1 liquids.

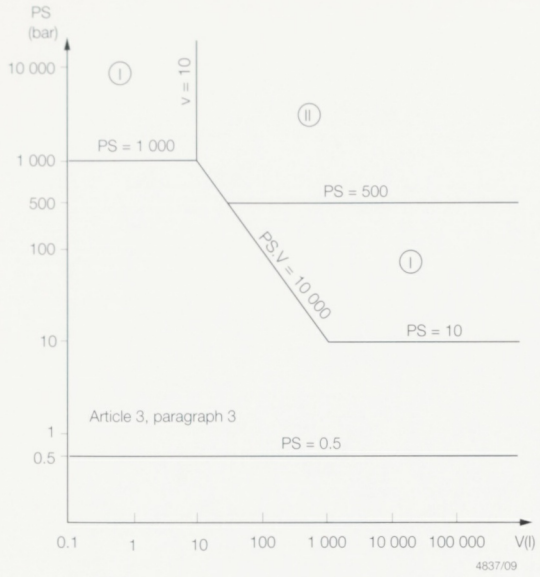


Table 4: Vessels containing Group 2 liquids.

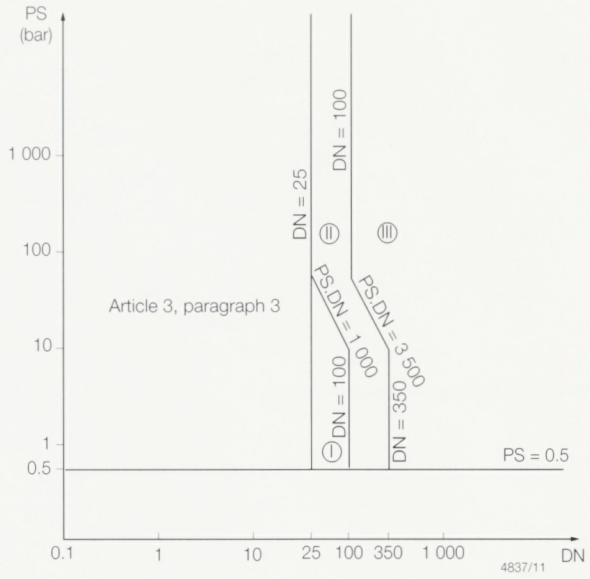


Table 6: Piping for Group 1 gases, vapours and liquids with a vapour pressure at the maximum working temperature greater than 0.5 barg above atmospheric pressure. Additionally, piping for unstable gases which fall into category I or II must be classified as category III.

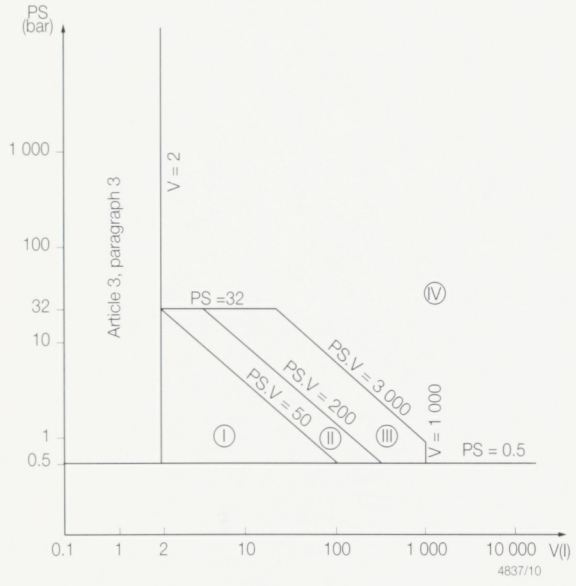


Table 5: Fired or heated pressure equipment for generating steam or superheated water at a temperature greater than 110°C with a risk of overheating. Additionally, all pressure cookers must be classified as at least category III.

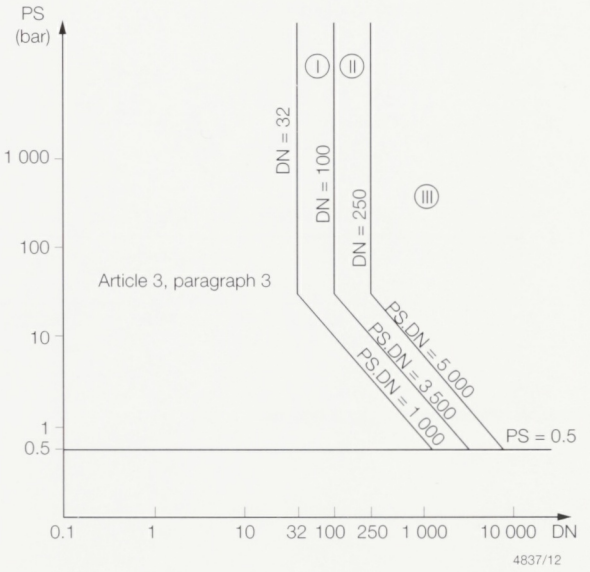


Table 7: Piping for Group 2 gases, vapours and liquids with a vapour pressure at the maximum working temperature greater than 0.5 barg above atmospheric pressure. Additionally, piping for fluids with an operating temperature above 350°C which falls in category II must be classified in category III.

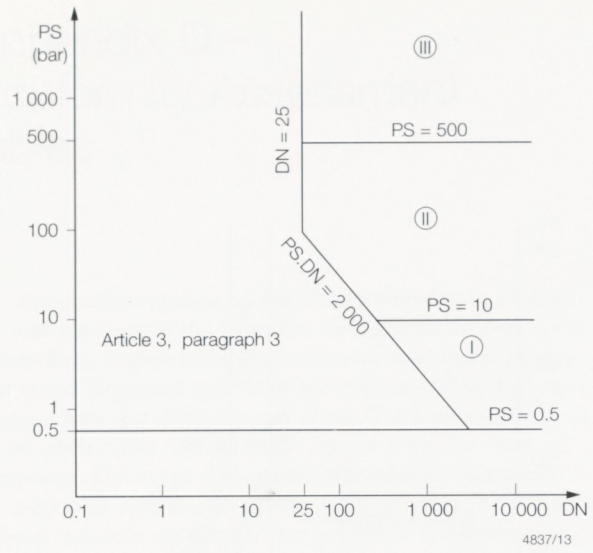


Table 8: Piping for Group 1 liquids.

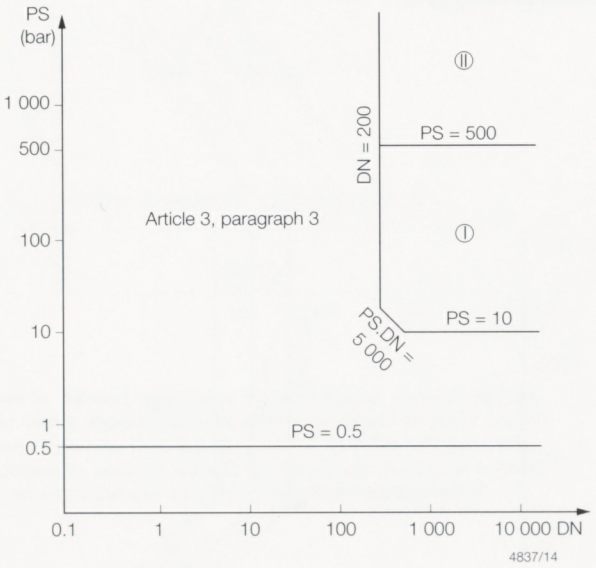


Table 9: Piping for Group 2 liquids.

LR *Technical Association*

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Human Factors in the Marine Environment

by R. S. P. Bell, C. K. Bright and J. V. Earthy



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Synopsis

There is an increasing awareness across the maritime industry of the significance of the human element in marine safety. However, despite this growing awareness, emphasis is still placed upon addressing technical issues and providing technical solutions as opposed to addressing human issues in maritime operations. Commonly, views such as "human issues are common sense", or conversely "human behaviour is too complex to consider in any systematic way" prevail and inhibit progress in this important area. An opportunity exists to address human element issues in a systematic way, through the application of knowledge and methods from the field of study known as Human Factors (HF). This Paper provides a detailed insight into HF, a multi-disciplinary field which brings together knowledge from the human sciences and from engineering to address the specification, design and assessment of work systems which take into account both the capabilities and the limitations of human performance. The aim of the Paper is to serve as an introductory document to those wishing to know "What is Human Factors?", "What is its role in addressing the human element in marine safety?", and "What is the current status of human element initiatives in the maritime industry?".

1 Introduction

There is an increasing awareness across the maritime industry of the significance of the human element in marine safety. Classification societies (Ref. 1), Underwriters (Ref. 2), and P&I Clubs (Ref. 3) have all identified the need to address the human element. In a submission to IMO's Maritime Safety Committee in 1995, Rear Admiral Card from the United States Coast Guard (Ref. 4) underlined the breadth and importance of the human element maritime issues when he wrote:

"There is a critical need to address people-issues... an assessment must be made with respect to the entire process, including navigating the vessel, cargo loading and unloading, and responding to emergencies."

Developing upon the 'people issues' identified in the quote from Rear Admiral Card, cited above, Table 1 details a broad range of ship operations and the associated human element issues.

Table 1
Human Element Issues and Ship Operations (based on information in [Ref. 1])

Ship Operation or Feature	Associated Human Element Issues
Ship design and equipment	Workspace layout Workload Bridge design Alarm displays Operating procedures (availability, accessibility) Computer based systems (usability)
Loading operations	Procedures (availability, accessibility) Computer based systems (usability) Information format and presentation
Navigation	Equipment displays Communication (person-to-person, quality, teamwork) Procedures
Maintenance	Workspace layout Workload Communication (person-to-person, teamwork) Procedures (availability, accessibility)
Emergency procedures	Evacuation behaviour Ship design/layout Training Communication (person-to-person)
Watchkeeping	Workload/fatigue Training Communication (person-to-person)
Radio communications	Equipment displays Communication (person-to-person) Procedures (availability, accessibility)

Lloyd's Register (LR) has a clearly stated aim to play a leading role in the setting, maintenance and application of proper standards of safety and quality in shipping. This aim is achieved, in part, through involvement in the development and application of Rules that address the technical requirements of ship design, construction and, to a lesser extent, operation. The Rules have been developed in response to changing technologies, extensive research and development, and service experience. Correct application of the Rules together with the survey process reduces the occurrence and extent of technical failures. Given LR's objective in respect of safety and quality in shipping, it is important that LR takes a leading role in addressing, and facilitating the consideration of, human element issues in maritime operations.

The importance of human element issues is by no means peculiar to the maritime industry. As well as the other transport industries, such as the aviation, railway and automotive industries, the nuclear, chemical and oil and gas process industries, are all concerned with identifying means of addressing the human element.

Technological and commercial developments have lead to a greater emphasis being placed upon consideration of the role of human performance and human reliability in the marine industry. Some of the central factors are set out below:

- Improved levels of machinery and equipment reliability which have lead to greater awareness of human performance and human reliability issues.
- The use of increasingly complex ship-board systems which have introduced new issues concerning job organisation, ease of use, and training needs.
- Reduced manning levels which have lead to changes in workload and working patterns.
- The increasing use of multi-cultural crews have highlighted the importance of communication and its impact upon normal and emergency operations.

To reduce the number of accidents and incidents it is necessary to improve the understanding of the underlying causes of human error, and to better understand the factors that affect human performance in relation to the technical systems being operated and the environment in which work is taking place.

Systematic assessment of the human element is contingent upon a thorough understanding of human behaviour and human performance in the context of work systems; for example, in the marine context an understanding of the issues in the design and operation of ships.

The discipline of Human Factors (HF), or ergonomics, which has developed over the last 60 years, has built up a large body of methods and guidelines for analysing, designing for, and evaluating the human element. Supporting these methods and guidelines are models, data and knowledge on human behaviour and human performance drawn from a range of disciplines and from a range of industry experience. HF methods and guidelines can be used alongside traditional engineering methods during the design, development and operation of work systems. While most industries recognise the importance of the human element, the uptake of HF methods and tools varies.

It is the HF discipline and its potential application to the marine environment that is the subject of this Paper. The Paper considers the role that HF can play in addressing, at a practical level, the reduction of human error and as a consequence result in improvements in marine safety. The Paper describes the background and scope of HF, describing the current developments and human element initiatives within the international maritime community, and concludes with a discussion of the way ahead for both LR and the maritime community as a whole.

2 The Human Element in Marine Casualties

Human error is seen as a major contributor to marine casualties. A commonly quoted statistic is that 60-80% of marine casualties are caused by human error. Such a statistic is derived from the kinds of analysis of causes of casualties such as that shown in Figures 1a, 1b and 2.

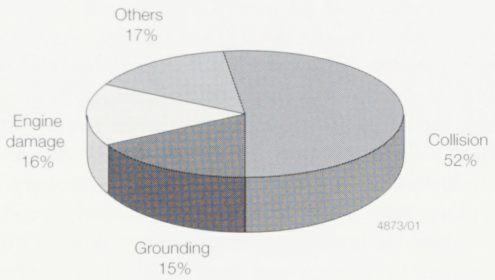


Figure 1a
Breakdown of Marine Accidents, Judgements in 1993 (Japanese waters) [Based on (Ref. 2)]

The accidents and incidents described briefly below serve to demonstrate the diversity of non-technical failures and errors and their impact upon maritime safety.

- The grounding off the Shetland Islands of the crude oil tanker Braer in 1993 highlighted a number of human and organisational errors that contributed to the accident (Ref. 5 and Ref. 6). For example, these errors included issues relating to:
  - *"...a serious dereliction of the Master's duty to preserve the seaworthiness of his vessel and the safety of his crew."* A comment made in the investigation report (Ref. 5, Clause 18.6) in respect of securing steel pipe sections which had broken loose and which lead to damage of the vessel's diesel oil supply and subsequently to the grounding of the vessel.
  - on-board bridge duty practice where navigation officers and ratings were allowed to spend entire periods of duty inside the wheelhouse, which in heavy weather conditions (particularly) was considered in the investigation report (Ref. 5, Clause 18.17) as *"an unseamanlike practice"*.

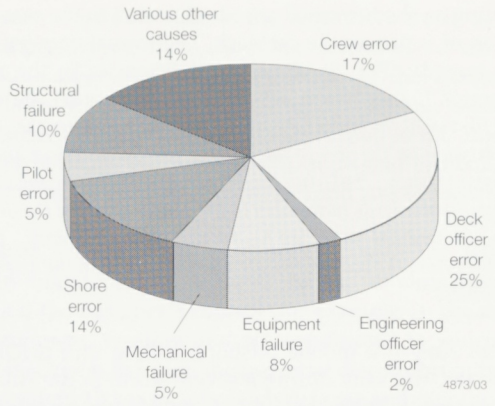


Figure 2
Main Causes of UK P&I Claims [Source (Ref. 3)]

- The investigation into the grounding of the Passenger Ro-Ro ferry Stena Challenger in the approach to Calais highlighted a number of human errors which contributed to the incident. These included *"...the lack of adequate monitoring of the vessel's exact position. ...poor communication on the bridge of the Stena Challenger; [and] poor passage planning with respect to pilotage..."* (Ref. 7; page 1).

- The capsize of the passenger Ro-Ro ferry Herald of Free Enterprise bound for Dover from the Belgian port of Zeebrugge highlighted a range of human and organisational errors. The capsize was the direct result of various factors. These included excessive trim forward due to the need to ballast the vessel to meet the loading ramp height; the open bow door, which was not visible from the navigating position; and the fact that the vessel was rapidly

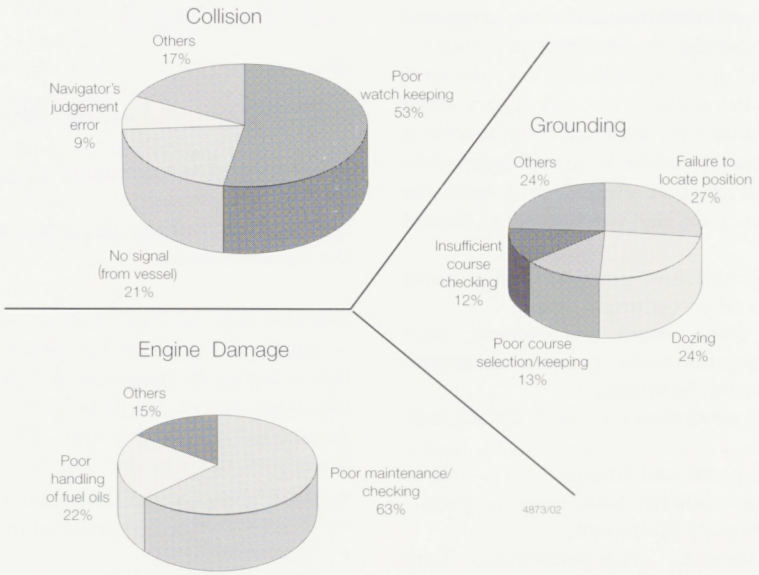


Figure 1b
Breakdown of Marine Accident Causes, Judgement in 1993 (Japanese waters) [Based on (Ref. 2)]

turning as she increased speed which led to the accumulation of water on the car deck. The formal enquiry into the tragedy (Ref. 8) identified deficiencies in the ferry operator. Justice Sheen, who headed the inquiry, stated:
"At first sight the faults which led to this disaster were the.. error of omission on the part of the Master, the Chief Officer and the assistant bosun.... but a full investigation into the circumstances of the disaster leads inexorably to the conclusion that the underlying or cardinal faults lay higher up in the Company... From top to bottom the body corporate was infected with the disease of sloppiness."

- *Ocean Ranger*, a mobile offshore drilling unit (MODU), capsized and sank during a severe storm in the Atlantic Ocean on 15 February 1982. A significant contributory cause of the accident identified in the accident report (Ref. 9) was the failure of first the automatic control, and subsequently the manual control, of the rig's ballast system. In its findings, the investigation report listed a lack of detailed instructions in the use of, and training in the operation of the Ocean Ranger's ballast system. Furthermore, it was identified that the design of control rods used to manually control the ballast system's valves was such that the rods *"...had considerable potential for inducing inadvertent human error."* An individual operating the control rods had no direct means of feedback to inform them whether they were opening or closing the valves. Although the investigation was unable to state conclusively, it was postulated that the ballast control valves may have inadvertently been opened, rather than closed, thereby exacerbating the situation on the rig which lead to its capsize and sinking.

- An oil tanker *British Trent* was in collision with a bulk carrier *Western Winner* on 3rd June 1993. The investigation into the accident, which occurred in conditions of restricted visibility, identified a number of contributory factors. These factors included an inadequate use of radar by both vessels given the prevailing weather conditions which were causing reduced visibility; a lack of an effective lookout by the *British Trent*; and unfamiliarity with the area combined with a lack of a passage plan on behalf of the Master of the Western Winner. The investigation report (Ref. 10) also identified that the judgement of both Masters' in the build up to the collision may have been impaired due to fatigue and stress.

Although the accidents listed above are only a very small proportion of accidents that have involved human error, it is possible to gain an insight from the accidents reports into the wide range of the factors that affected, or shaped, the performance of the crews on the vessels. These factors include:

- Inadequacies in organisational practices, and in vessel operating routines and procedures.
- Inadequate vessel management, (for example, poor performance of navigation tasks, and poor communication between crew on the bridge).
- Poor environmental conditions (i.e. low visibility, traffic density).
- Personal factors (i.e. stress and fatigue).
- Lack of training and familiarity with control systems.
- Poor ergonomic design of equipment.

A further discussion of these and other performance shaping factors is given in Section 4 of this Paper where HF approaches to the study of human error are described.

3 The Human Factors Discipline

3.1 Historical Development

The recognition of HF as a distinct and important discipline grew largely out of the technological developments that took place during the Second World War. Technological advances in military equipment and, following the War, in civilian applications prompted the need to consider the human operator in the design and development of equipment. To achieve acceptable levels of performance through utilisation of increased levels of automation it was no longer feasible to expect the human operator to merely adapt to equipment – the approach that prevailed with the use of earlier industrial automation. The use of technology in the workplace saw a shift from predominantly production tasks, where the human was engaged in making or doing, to predominantly control and supervision tasks, where the human was engaged in thinking about how things should be done and planning how to do them (Ref. 11). The operator was increasingly concerned with the management and utilisation of information, as opposed to being concerned with the processing and production of energy or materials. Furthermore, increased levels of automation shifted the operator away from direct involvement in a process to tasks concerned with control of processes via control equipment, hence he was removed from the actual process itself.

As Hollnagel (Ref. 11; pages 2-3) writes:
"The requirement that the human should become a controller of machines created a host of new problems. For instance, it became important to know exactly how much a person could attend to, discriminate between, evaluate, remember, manipulate, etc. either simultaneously or over a period of time. Furthermore, since the work environment often became more demanding (in planes, ships, vehicles etc.) it was also necessary to know what a person could tolerate in terms of vibration heat, cold, pressure, noise (and silence!), light, acceleration etc."

3.2 Scope of Human factors

HF developed as a discipline which addressed the recognition that it was necessary to design equipment, procedures and tasks (i.e. work systems) that matched the capability of the human element.

Edwards (Ref. 12; page 5) describes HF as:
"...concerned to optimise the relationship between people and their activities, by the systematic application of human sciences, integrated within the framework of systems engineering."
As implied by this definition, HF draws upon a range of disciplines, in particular:

- Psychology
- Engineering
- Ergonomics
- Medicine/Physiology
- Computer science

A useful model for describing the coverage of HF was put forward by Professor Elwyn Edwards and extended by Hawkins (Ref. 13). The SHEL model, (*Software, Hardware, Environment, Liveware*) describes the key components, along with their interfaces, of a work system which are the focus of HF (see Figure 3).

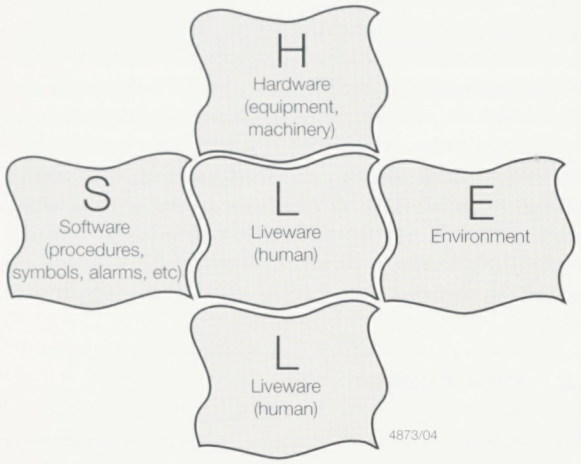


Figure 3
The SHEL Model of Human Factors [Source (Ref. 13)]

If the interface between the human *operator* and any of the other components is inadequate then there is an increased potential for human error leading to reduced safety and/or reduced work efficiency. As is expressed by the SHEL model in Figure 3, the HF philosophy proposes that it is necessary to design the surrounding components to match with the characteristics and capabilities of the human, as opposed to trying to make the human fit in with, or adapt to the other components. Implementing such a philosophy obviously requires an understanding of the human, and it is here that the various contributions from the human sciences come into play. For example:

- psychology provides insight into the cognitive aspects of human performance (such as perception, information processing, memory and learning) as well as into behavioural aspects such as reaction to stress,
- ergonomics (in particular anthropometry), along with physiology, provides background information on human physical size and shape characteristics, and the effects on human performance of environmental factors such as heating, lighting, noise and vibration.

Summarising each of the component interfaces in the SHEL model in turn:

Liveware – Hardware is concerned with the man-machine interface, covering aspects such as the design of seating to fit the sitting characteristics of the human body, the design of displays (such as navigation displays and computer displays) to match the sensory and information processing characteristics of the user, and the design of controls ("knobs and dials") so that they are properly located, labelled or coded, and can be manipulated.

Liveware – Software (where the term software is used to encompass more than computer software) covers non-physical aspects of the system such as the design and provision of procedures, operating instructions, checklists, and signs and symbols. Key issues related to this interface are *interpretation* (of, for example, signs and symbols) and *memory* (of, for example, procedures and task sequences etc).

Liveware – Environment is concerned with the working environment. Some elements of the environment are beyond the designer's control (for example, in the marine environment, weather and sea conditions) in which case the objective is to lessen the potential discomfort or impact upon safety. Other factors, such as noise and vibration can be controlled to a greater extent, but are often constrained by economic considerations.

Liveware – Liveware is the interface between people, covering communication, teamwork and authority relationships. Communication is an increasingly important issue with greater use of multi-cultural crews. Taking a lead from Cockpit Resource Management (CRM) in the aviation industry, Bridge Resource Management is gaining acceptance as a necessary part of team training of a ship's crew. The objectives of resource management training is to make personnel aware of the impact on overall team performance of such issues as communication, crew co-ordination, and teamwork, and to develop people's skills in these areas.

In summary, the HF discipline embodies a set of principles, supported by a broad range of methods and guidelines, that together are concerned with the optimisation of the interfaces between the human and other components of a work setting (as illustrated in the SHEL Model shown in Figure 3). Depending upon the context in which HF is applied, optimisation may be in terms of safety or general human performance (for example, performance in terms of efficiency, effectiveness, or job satisfaction). The key to HF principles is the view, derived from the human sciences, that the human is the central component of a work system. In adopting this view, HF can be seen to take a 'human-centred', as opposed to 'technology-centred', view in the design, operation, and future development of engineered systems. The methods and guidelines that support the HF principles are described in the following section.

4 Human Factors Methods and their Application

4.1 The Use of Human Factors Across Industry

As was stated previously, the extent to which HF methods are used varies across industry. However, typically, HF is used in one of the following ways:

- To inform the system design/re-design process (for example, when designing a control room layout, designing a computer system user interface, devising a training programme, or assessing the impact of changes in job design).
- To support the assessment of workplace health and safety.
- To identify critical human operations (for example, as part of a quantified risk assessment within a safety case, or in support of the design of a safety management system).
- To aid accident investigation in determining contributory (human) causes.

There exists a broad range of HF methods that are used to conduct systematic assessments of the type described in the previous section. The range of these methods is too broad to cover adequately in this Paper. Instead a subset of methods, selected for their potential applicability to the marine industry, will be described in brief:

- Task Analysis.
- Human Error and Human Reliability Assessment.
- Audit or Assessment against HF Standards or Guidelines.

Typical uses of the methods listed above are summarised in Table 2. Underpinning the use of such methods, the HF practitioner will utilise, as appropriate, one or a number of core techniques in order to gather the necessary qualitative and quantitative data. Commonly used techniques are listed in Table 3.

Table 2
Core HF Methods and their Typical Uses

HF Method	Typical Uses
Task analysis	Job design User – system interface design Training needs assessment Workload assessment Basis of human error/human reliability assessment
Human error assessment	Human error identification Identification of critical tasks Identification of risk mitigating measures
Human reliability assessment	Quantification of human error probabilities as part of quantified risk assessment
Audit/assessment against HF standards and guidelines	Conformance assessment (against standards) Assessment against best practice (guidelines) HF requirements analysis Provision of design recommendations

Table 3
Classes of HF Methods and Techniques

Common HF Methods	Techniques for Data Gathering
• Task analysis • Human error and human reliability assessment • HF audit or assessment • Computer system usability	• Interview/questionnaire • Observation • Document review and analysis (eg. procedures) • Empirical (experimental) studies • Assessment using HF checklists/ guidelines

Each of the methods are now described in more detail.

4.2 Task Analysis

Task analysis (TA) is *'the study of what an operator is required to do in terms of actions and cognitive processes to achieve a system goal'* (Ref. 14). Task analysis is a global term for a variety of specific techniques which collect information about tasks, organise it and use it to make various judgements and design decisions. Appendix A gives a more detailed description of some of the more common TA techniques and Appendix B contains an illustration of one particular TA technique, Hierarchical Task Analysis (HTA), that was used in LR's LOADPLANNER R&D project. The primary purpose of task analysis is to compare the demands of the system with the capabilities of the human operator, and if necessary to change those demands to reduce the potential for error and improve human performance. It is a process of data collection, representation, analysis and sometimes simulation.

The benefits of carrying out a task analysis are dependent upon the goals of the study, or on the particular human factors issue addressed. The main generic benefits from a safety and quality perspective are, however, that a task analysis:

a) allows mismatches between a design engineer's view of a 'system' and the human capabilities needed to operate the system to be resolved, and the potential for error to be reduced;
b) provides a formal, structured and documented assessment of the human contribution to system performance, upon which to base subsequent design decisions.

Within the context of the marine industry, task analysis methods as set out above could be used to address a number of current issues. Task analysis could be used to support the design and impact assessment of the use of new integrated bridge system technology; for example the integration, or overlay, of electronic charts (ECDIS) and radar plotting to support navigation is one particular topic of concern. More generally, task analysis could be used to assess the implications of reduced manning on board ship, by analysing the implications for workload, and in determining any changes in working patterns and training needs.

4.3 Human Error and Human Reliability Assessment

4.3.1 Growing focus on Human Error in Industry

In Section 2 of this Paper it was stated that 60-80% of marine casualties are caused by human error. Such a statistic is very much in line with published estimates of the percentage of system failures caused by human error that have been made from studies across a broad spectrum of industries (see Figure 4). This figure also illustrates the rise, that has been detected by those studying the area, in the proportion of human error as opposed to equipment, or technical failure as a contributor to overall system failures. Improvement in the reliability of workplace technology, together with the increasing complexity of that technology, has raised the prominence and significance of human reliability.

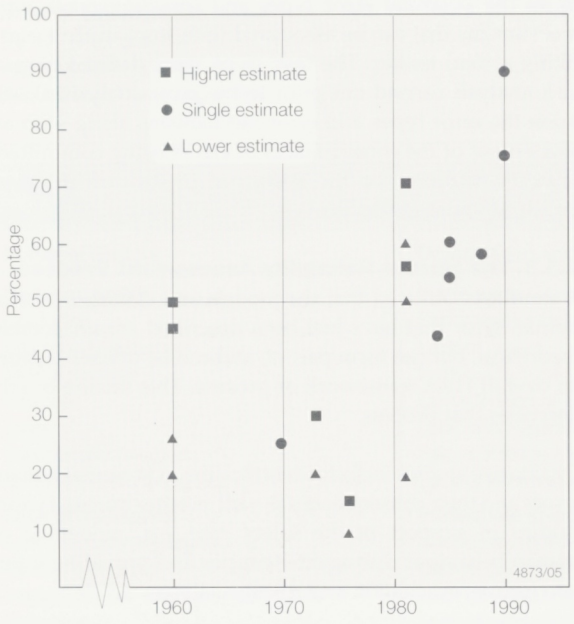


Figure 4
Estimates of the Percentage of System Failures Caused by Human Action [Source (Ref. 11)]

In addition to systematically addressing human factors principles and analysing task requirements to optimise human performance, industries in which a safety case regime exists, have also been assessing the reliability of human operators. In the nuclear, chemical process and more recently the offshore industry, the contribution of the human element to risk has been assessed as part of the safety case development. This has typically included both qualitative and quantitative assessments. Growing interest in Formal Safety Assessment (FSA) for shipping (Ref. 15) increases the relevance of human error assessment and quantitative Human Reliability Assessment (HRA) techniques within maritime operations.

Analysis of human error serves two main purposes. Firstly it can be used to assess design or redesign requirements in terms of the physical, procedural, and safety management system safeguards that are needed in a given work context. Secondly, human error analysis has a role within incident and accident investigation where it can be used to determine retrospective measures to avoid, or reduce the likelihood of, recurrence of accidents caused by human error.

4.3.2 Individual and Organisational Error

When considering the '60-80% statistic' it is important to recognise that such a figure includes not only errors by individuals, or teams of individuals, but also what can be considered as 'organisational errors' (for example, flaws in a management system, or in the inherent design of a technical system). Such organisational errors can contribute to, or can combine with, errors by individuals which together can lead to an accident or incident.

In underlining the distinction between organisational and individual error a further distinction is made between *active* and *latent* errors (Ref. 16 and Ref. 17). The difference between these two classes of error relates primarily to the length of time that passes before human failure makes an impact upon system safety. It also relates to the focus of the source of the error. Active errors tend to lead directly to an unsafe situation. They may be the result of an individual's or group of individuals' actions at the point of the accident or incident. Latent errors, on the other hand, are errors that can often take a long time to reveal themselves and are the consequence of human actions or decisions often made at a management or corporate level.

Several of the marine casualties summarised earlier in Section 2 provide examples of the mix of active and latent errors. The investigation into the Braer accident highlighted examples of both (active) navigational errors by the ship's crew and latent errors such as flaws in emergency preparedness and communications. The investigation also highlighted the introduction of flaws even earlier in the ship's history through design errors relating to inadequate vent design and an inadequate fuel monitoring system (Ref. 6). Further illustration of the distinction and significance of active and latent errors is given most poignantly in Justice Sheen's summing up of the investigation into the *Herald of Free Enterprise* tragedy (Ref. 8) cited earlier in Section 2.

Organisational Error

Safety Management Systems (SMS) are a key feature of attempts to reduce organisational errors and their potential impact on safety. At the highest level, such systems can be seen to define, document and provide the means to subsequently monitor the provision of the necessary resources, personnel, procedures, and communication mechanisms, that are required to fulfil defined safety and business performance objectives.

A central objective underlying such management systems is the provision of safeguards to reduce the likelihood of inadequacies in an organisation that can compromise safety and business performance.

Individual Human Error

At the level of error of individual human error, a number of models and classifications have been developed. These models have addressed the psychological aspects of error, looking at factors such as learning, memory, attention,

pattern recognition, planning, and communication (for a detailed review of the theoretical field of human error see Ref. 11 and Ref. 16).

Individual human errors (i.e. the failure of planned actions to achieve their desired goal) have tended to be divided into two main groups, each having different underlying causes and each needing to be addressed in a different way (Ref. 16):

Slips and lapses These are failures of execution of a planned set of actions. The plan of action chosen is appropriate, but errors occur in the way the necessary actions are carried out. Slips relate to observable actions and are associated with failures in attention on behalf of an individual. Lapses are internal events in the 'mind' of the individual and relate to failures of memory.

Mistakes These relate to the selection of a wrong or inadequate plan of action for a particular goal.

Based upon the psychological models of error, classifications have been constructed which provide a framework for identifying and describing error types, error causes, and the factors influencing their occurrence. In the HF literature and in the human error analysis methods that utilise these classifications the following distinctions are made concerning the components of human error:

External error modes

All errors can be classified by their 'external error modes' (Ref. 18), that is the way in which an error is revealed (hence the use of the term 'external'). The basic set of error modes as defined by Swain and Guttman (Ref. 19) are shown in Table 4.

Table 4
External Error Modes [Source (Ref. 19)]

Error of omission	• Act omitted (not carried out)
Error of commission	• Act carried out inadequately • Act carried out in wrong sequence • Act carried out too early/late • Error of quality (too little/too late)
Extraneous error	• Wrong (unrequired) act performed

Error causes or error mechanisms

These are causes, defined in psychological or ergonomic terms, of the external error modes. For example, 'act omitted' (error mode) may have been due to 'lack of vigilance' or 'distraction' (error mechanisms). One classification of error mechanisms developed in (Ref. 20) is given in Table 5. In a given context any one of these error mechanisms may be the cause of a particular error mode.

Performance shaping factors

These are the factors that can affect human performance and in so doing can bring into play the psychological error mechanisms of the type described above and shown in Table 5. Performance shaping factors include such factors as the level of training, skills and experience of an individual, the working environment, and the organisational culture. Kristiansen (Ref. 20) has drawn up a set of performance shaping factors (or as he refers to them, 'basic causal factors') which are particularised for the marine environment – see Table 6.

Analysing human errors in the way described above enables the identification of appropriate error reduction, or preventative, measures. Such measures may typically cover such aspects as changes in job design, improved ergonomic design of equipment, or improved training. A more detailed list of preventative measures in the context of marine operations is shown in Table 7.

An example of human error analysis and the distinctions between the components just described above, is illustrated in an extract of an analysis undertaken in the offshore industry in Figure 5. The extract from the analysis illustrates the potential error types and (psychological) error mechanisms that can be associated with steps in the task of filling a road tanker. The task steps were derived from a task analysis carried out prior to the error analysis. Based upon the error types and error mechanisms along with an assessment of the consequences of errors being committed, recommendations for the design of procedures, training and equipment can be made.

4.3.3 The Human Reliability Assessment Process

It should be stressed that the models and classifications of human error that have just been described are not merely theoretical, but can form part of, and can be utilised within, an overall HRA framework or process. This section briefly describes that process.

Qualitative studies include identification of potential human errors and their consequences as well as other human factors studies in support of the safety case, e.g. modelling of human behaviour during emergencies and providing input into escape, evacuation and rescue analyses.

Quantification of human error probabilities is achieved either through the use of relevant human reliability data, where such data exists, or by using a formal HRA technique. A useful review of HRA techniques is provided in (Ref. 21). An outline of the HRA process is presented in Figure 6.

Before any attempt to assess potential human errors (or to quantify human reliability) is made, it is essential that a task analysis is carried out, as discussed above. The task analysis identifies what the human should be doing, how he should be doing it, when he should act, what controls and displays he should use and what other factors might influence his performance. It is an essential precursor to any human error or reliability analysis.

Human error identification is essentially analogous to the process of hazard identification in the risk assessment field. Indeed, techniques such as Hazard and Operability (HAZOP) study and Failure Mode and Effects Analysis (FMEA) can, and have been, adapted to account for human failures.

Table 5
Classification of Human Error Mechanisms [Source (Ref. 20)]

Set objective or give priority	**Analyse and decide**
Ignore requirements of the situation	Out of sight out of mind
Suppress own opinion	Wrong condition – good rule
Ignore problem	Overlook side-effects
Did not take on the challenge	Did not anticipate situation
Sense and detect	Wrong understanding of the situation
Lack of vigilance	Wrong analysis – causality
Visual illusion	Did not understand dynamics
Perceive, identify and discriminate	Great complexity
False hypothesis, high expectancy	Right condition – wrong rule
Overlook countersigns	No double checking
Habit, stubbornness, stereotype fixation	**Act or control**
Perceptual confusion	Action without intention
Recall	Spontaneous (non-planned) action
Forget isolation act	Distraction
Mistake alternatives	Omission following interruption
Other slips of memory	Reversal
Order or communicate	Repetition
Slip of the tongue	Motor variability
Vague/obscure speech	Slip
Contradictory/conflicting orders	Spatial disorientation
	Slow feedback
	Confusing noise

Table 6
Performance Shaping Factors in the Context of the Marine Environment [based on (Ref. 20)]

Personal Factors	Organisation and Leadership	Task and Working Conditions
Reduced ability	**Inadequate vessel management**	**Physical stress**
Confusion	Subordinate's lack of discipline	Noise, vibration
Emotionally disturbed	Lack of orders	Sea motion, vibration
Mental disorder	Inadequate supervision of work	Climate, temperature
Sickness	Co-ordination of work	Toxic substance
Drug	Lack of co-operation	Extreme environmental loads
Functionality retarded	Failure of leadership, iniative	**Task load**
Reduced vision or hearing	Lack of information	Too high task load
Lack of motivation	**Inadequate shipowner management**	Too low task load, boredom
Lack of personal integrity	Inadequate routines and procedures	Unfamiliar task
Lack of incentives	Lack of priority for maintenance	Tasks competing for attention
Inadequate self-discipline, job morale	Lack of resources to maintenance	**Ergonomic conditions**
Sabotage	Lack of resources for safe operation	Anthropometric factors
Prestige	Inadequate follow-up of vessel organisation	Lack of information
Macho-culture, cowboy mentality	**Inadequate manning**	Inadequately presented information
Recklessness	Crew size too small	Inadequate tool or aid
Lack of ability	Outdated or false certificates	Inadequate illumination
Task know-how, experience	Highly varying competence	Workplace messed up
Lack of training, routine	Inadequately trained personnel	**Social climate**
Inadequate familiarity with vessel	**Inadequate routines**	Conflicts in terms of role and authority
Lack of language	Lack of work leadership	Inadequate communication
Inadequate mathematical skills	Navigation	Lack of cultural awareness
Wrong assessment	Engine room operations	Lack of co-operation
Lack of practical skills	Vessel safety monitoring	Conflicts
Lack of seamanship	Maintenance	**Environmental conditions**
Physiological stress	Cargo handling	Too low visibility
Lack of sleep	Emergency preparedness	Too high traffic density
Fatigue		Hindrances in the seaway
Disturbance of diurnal rhythm		Restricted fairway
Irregular meals		
Psychic stress		
Personal conflict		
Panic		
Time pressure		
Problem of communication		
Superior work requirements		
Lack of job satisfaction		

Table 7
Preventative Measures in the Context of Marine Operations [Source (Ref. 20)]

Technical
Improved reliability and availability
Improved performance of systems exists
New functions of aids
Instrumentation, monitoring
Automation
Improved human-machine interface
Improved work-place conditions

Operational
Inspection methods
Maintenance procedures and methods
Operations procedures, system documentation
Manning and watch systems

Personnel
Selection and checking of competence
Education and training
Leadership and supervision
Motivation: modification of attitudes
Development of social climate

Safety management
Management: organisation, routines
Risk analysis: safety case
Inspection and auditing
Experience feedback, learning
Emergency planning and training
Health, environment and safety work

Top level management
Develop safety policy
Budgeting, resource allocation
Leadership philosophy

Infrastructure
Weather forecasting/routing service
Development of tug and salvage service
Strengthen port state control
Upgrade VTS facilities and service

Task Step	Error Type	Recovery Step	Psychological Mechanism	Causes Consequences and Comments	Recommending		
					Procedures	Training	Equipment
51.1	Action too late	No recovery	Place losing error	Overfill of tanker resulting in dangerous circumstance	Operator estimates time/records amount loaded	Explain consequences of overfilling	Fit alarm-timing/volume/tanker level
51.2.1	Action omitted	5.2.4	Slip of memory	Feedback when attempting to close closed valve otherwise alarm when liquid vented to vent line			MMC of valve configuration
51.2.2	Action too early	5.2.2	Place losing error	Alarm when liquid draws to vent lines	Specify time or actions	Operator to count to determine time	
	Action omitted	5.2.2	Slip of memory	As above and possible over-pressure of tanker [see step 5.1.2.3]			Mimic of valve configuration
51.2.3	Action too early	No recovery	Place losing error	If valve closed before tanker supply valve, overpressure of tanker will occur		Stress importance of sequence and explain consequences	Interlock on tanker vent valve
	Action omitted	5.2.6	Slip of memory	Automatic closure on loss of instrument air			Mimic or valve configuration
51.2.4	Action omitted	5.2.2	Slip of memory	Audio feedback when vent line opened		Explain meaning of audio feedback	Mimic or valve configuration
51.3	Action omitted	No recovery	Slip of memory	Latent error	Add check on final valve positions before proceeding to next step		Mimic or valve configuration

Figure 5
Example extract of human error analysis (taken from [Ref. 18]; original source [Ref. 30])

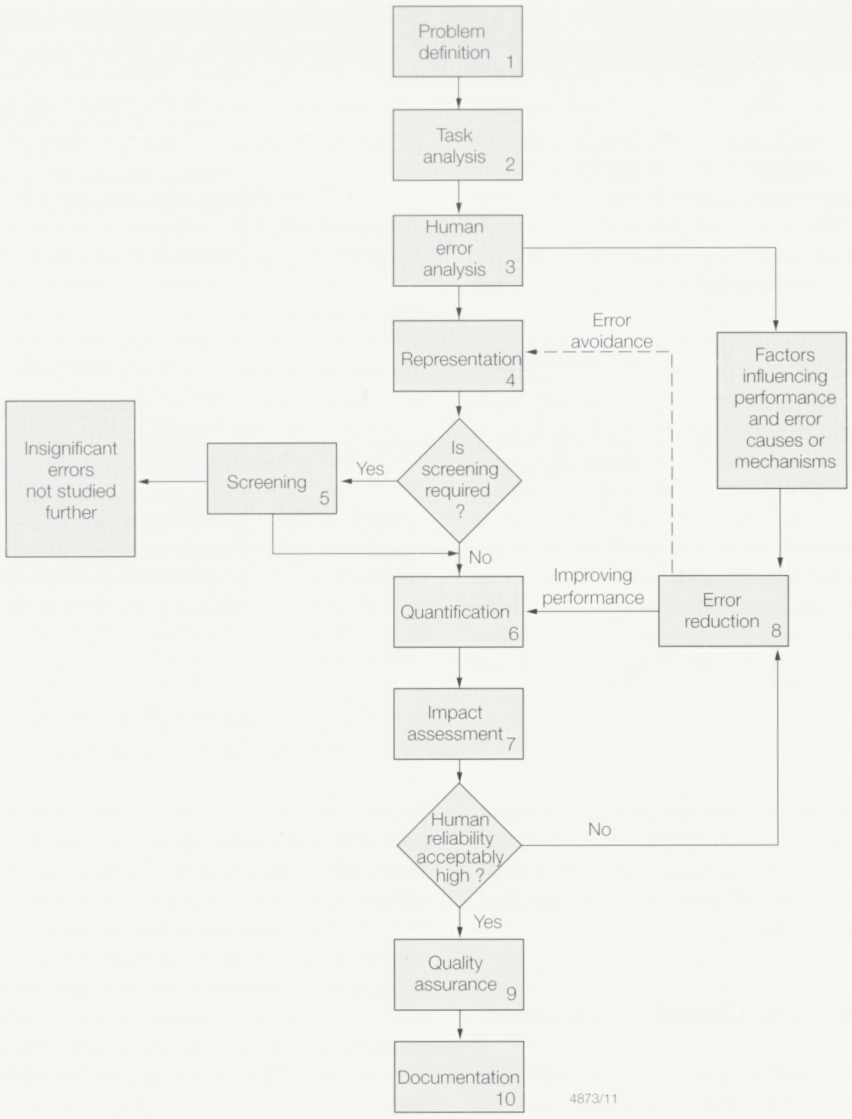


Figure 6
Kirwan's HRA Process Diagram [Ref. 18]

More typically, however, potential human errors are identified using a checklist approach, related to potential error types. This identifies the errors in terms of the external error modes (i.e. 'was an action omitted?', or 'carried out too early, or too late?' etc.).

Following the identification of potential error types it may be relevant to then consider the consequences of the potential errors identified in line with the general process of hazard analysis. At this stage, errors may be screened from further detailed consideration if, for example, the consequences of error are insignificant, or the potential for recovery is judged to be very high, or, if the probability of the error occurring is judged to be so remote as to be considered incredible.

The benefit of HRA over solely qualitative studies is that it allows direct comparison of the risk reduction which may be achieved through various design options, and therefore facilitates the process of cost-benefit analysis.

4.4 Audit and Assessment Against Human Factors Guidelines and Standards

Alongside the methods described above, there is a large body of HF design guidance, and an increasing number of international standards, covering the range of activities relating the human component of systems to engineering. Indicative examples of existing and developing HF guidelines and standards used in a range of industries, including the marine industry, are referenced in Table 8. These standards and guidelines can be used as a support to the design process, by ensuring consideration of HF 'best practice', or in a formal way by ensuring (mandatory) conformance to particular HF principles and HF design requirements. To date, the mandatory use of HF standards has, in the main, been limited to the design of military equipment and systems.

It is not possible to include a comprehensive set of HF guidelines in this Paper, however, it is instructive to include

Table 8 Key HF Standards and Guidelines		
Ergonomic design of control centres	ISO 11064	Draft international standard for ergonomic design of industrial control rooms
Ship's bridge layout and associated equipment – Requirements and Guidelines	ISO 8648	International standard and guidelines on ship's bridge layout
Standard practice for human engineering design for marine systems, equipment and facilities	ASTM F 1166-95	American Society for Testing and Materials Defence Standard for marine equipment
Human factors for designers of equipment	DEF-STAN 00-25	UK Defence Standard for defence equipment
Guide to reducing human error in process operations	UK Human Factors in Reliability Group (HFRG) Report SRDA-R3	Guidelines on assessing human reliability in process industry system design and operation. Guidelines applicable to wider industries
Ergonomic requirements for office work with visual display terminals	ISO 9241	17 part international standard on ergonomic design of computer system hardware and software; some parts draft some approved
Human centred design processes for interactive systems	ISO 13407	Draft international standard for interactive computer system development

some examples of guidelines in order to convey a flavour of what is contained in the texts listed in Table 8. To this end, Appendix C contains some sample guidelines. These have been selected to exemplify the HF issues that are described by the SHEL model (see Section 3.).

4.5 Computer System Usability Evaluation

It can be argued that computer systems simply represent another engineered component of a work system and, as such, while falling into the province of HF, they do not represent a special case. However, given their increasingly pervasive use, and the complex HF issues that they present, the design of interactive computer systems is currently an area of particular concern for HF. Consequently, the particular HF issues related to computer system usability warrant a brief discussion in this Paper.

The advances in computer hardware and software have lead to the development of increasingly interactive computer systems. Graphical user interfaces are common, and the utilisation of input devices such as a mouse, graphics tablets, touch screens, as well as voice input are used increasingly in addition to, or instead of, the more traditional use of a keyboard. Information systems enable the user to interact with and manipulate graphical objects as well as textual and numerical data. The initial use of software applications to undertake data processing and numerical calculations has expanded and software applications are now used to support such tasks as information retrieval, the design of engineering components, equipment condition monitoring, and industrial process control. Within the marine environment, computer based applications are found in a wide range of operations such as cargo loading, voyage planning and navigation, ship control and emergency management.

As well as having a direct impact upon user performance, poor usability has implications for human error and system safety when used in safety-critical, or safety-related, environments. Usability is commonly defined as *"The effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments."* (Ref. 22). A branch of HF known as Human-Computer Interaction (HCI) or software ergonomics has now evolved to carry out research, and to develop guidelines and methods to support the development of usable, 'user-friendly' computer systems.

In recognition of the importance of the usability issue, international standards are under development which address usability design (in Ref. 22 and Ref. 23). Within HCI, a range of methods and tools have been developed to ensure that usability issues are addressed alongside the functional and technical requirements of system specification, design and testing.

Aware of the considerable number of failed computer systems that did not adequately consider the needs of the user, HCI specialists advocate that the development of usable interactive computer systems is dependent upon a 'human-centred' development process. Such a process is one that consults with, and involves, a representative set of potential end-users throughout the development of a software product.

As a guide to developing for usability, Ref. 23 describes four main activities:

- **Specify the user and organisational requirements** in terms of effectiveness, efficiency and satisfactions; and the allocation of function between users and the system.
- **Understand and specify the context of use:** the nature of the users, their goals and tasks, and the environment in which a product is to be used.

- **Produce prototypes** and designs of plausible solutions.
- **Evaluate prototypes** and designs against user criteria.

There exists a range of methods, design guidelines, and tools to support the activities just described. These methods cover the following aspects of the development of a software product:

- Methods for capturing and representing user requirements. These requirements are in terms of the functional requirements to meet the needs of the user given their goals and the task environment.
- Methods and guidelines for screen/display design (for example the use of colour and symbols).
- Methods and guidelines for dialogue design (i.e. specification and design of the means and sequence by which the user can interact with, and get output from the system).
- Tools for developing rapid prototypes of a proposed system design.
- Methods for usability evaluation. Such methods enable the evaluation, with representative groups of users, of the usability of a prototype or finished product for the purposes of informing the on-going design, or re-design of a system.

4.6 Potential Application of Human Factors Methods in the Ship Life Cycle

A number of methods and sets of guidelines central to the HF discipline have been described in this section. There is a potential to apply these methods and guidelines across the ship's life-cycle. They can be used, for example, to:

- improve the design of on-board equipment and computer systems and overall layout of the working spaces such as the bridge and the engine room;
- define and allocate appropriate workloads to optimise crew performance and to reduce the likelihood of errors due to mental or physical fatigue;
- ensure the effective provision and communication of working procedures;
- determine necessary training needs, especially in respect to the use of new technology, or new manning strategies.

Furthermore, methods such as task analysis, and in particular human error analysis, can be used as a framework to aid accident investigation whereby a more detailed understanding of any human contribution to an accident can be gained and hence appropriate measures put in place to reduce the likelihood of re-occurrence.

There is therefore a broad range of applicability for HF within the marine industry. To date, however, the application of HF methods within the marine industry remains in its infancy with the majority of work having been carried out in the context of research. Much of this work has focussed on ship bridge design. A number of factors explain this specific focus. In particular, the broad range and interactive nature of tasks on the bridge make this an area where HF methods and guidelines are more readily applicable. A wide range of functions and tasks are carried out on the bridge covering, for example, navigation, communication, and condition monitoring. Techniques such as task analysis have been used to provide a framework whereby an appropriate division and allocation of bridge tasks can be determined and whereby equipment layout can be optimised according to the primary and secondary tasks of those on the bridge (Ref. 24). In a similar way, task analysis can be used to make assessments of workload, both mental and physical, and hence can be used to compare different bridge manning levels. Furthermore, there is an increasing use of bridge simulators and mock-ups in the design of advanced integrated bridge systems and HF methods can be used in defining the scope, and managing the evaluation, of simulation trials.

In the context of the marine industry overall, the wider uptake of HF still needs to be addressed. The HF discipline should be viewed as a resource which can be called upon to address many of the human element issues which are facing the industry. The challenge that faces the marine industry at present is to identify which particular HF methods offer applicable and practicable tools in addressing particular human element issues. During this process, due consideration should be given to the experience of those other industries that have encountered similar issues and that have undergone a similar learning process with respect to the application of HF.

5 Human Factors in the Context of the Marine Industry

This section describes a number of HF related initiatives and activities that are taking place within the maritime industry.

5.1 IMO Developments

The growing recognition of the importance of the human element in maritime safety has resulted in initiatives by the International Maritime Organisation (IMO), administrations, and classification societies.

Formal action to address the human element have only occurred relatively recently. It was in 1989 that IMO adopted Resolution A.675(16) committing the Organisation to examining the human element. This came about amid the growing evidence that the great majority of maritime casualties have been caused by the failure of management and operations rather than structures, machinery and equipment.

Initial IMO efforts have been directed at bringing about an integrated, systematic, broad-based approach to maritime safety which combines technological improvements with human element related considerations. In so doing, IMO has also been evaluating and taking into account the experience from other industries.

The initial papers considered at the sixtieth meeting of the Maritime Safety Committee (MSC 60) looked at how the IMO could use the human element to consider its own rule making process. Their approach was to request each of the sub-committees to examine the regulations they were responsible for against a set of agreed criteria. The results have been disappointing and have thus not been fully taken up by IMO. New approaches to help the various sub-committees continue to be developed.

To further progress this activity a joint MSC/MEPC (Marine Environmental Pollution Committee) working group was established. This group has piloted the ISM code through to its adoption in SOLAS and continues to deal with matters arising from its implementation. In parallel it has been considering how to develop a strategic approach for the Organisation to incorporate human element issues as an integral part of its work. The joint working group has now laid down a set of principles and is developing goals to provide a practical method of measuring the application of these principles.

Further subsidiary tasks, such as the creation of a glossary of HF terms to provide a common understanding and vocabulary, are also being worked on.

The clearest indications of IMO developments in respect of human element issues comes from the implementation of the ISM Code and the 1995 amendments to the convention for Standards, Training, Certification and Watchkeeping for Seafarers (Ref. 25).

5.1.1 The ISM Code

The ISM Code (Ref. 26) by virtue of its mandatory application, is considered instrumental in integrating human element and management relevant factors with traditional statutory and class related topics. The Code requires the development of a systematic approach to the management of safety, ashore and on-board. Management awareness, availability and accountability are key issues addressed by the Code.

The Code details its requirements under 12 headings (see Appendix D). Each represents an important component of a successful Safety Management System (SMS). It brings the benefits of a documented management system to the safety activities on-board ship. The aim of the Code is to contribute to the safety of life at sea and protection of the marine environment, in particular by improving:

a) the safety culture in the shipping industry, to be more proactive rather than reactive against near misses, accidents and serious casualties;
b) company organisation with respect to the levels of authority, responsibility and communication;
c) preparedness of personnel on board and ashore to deal with normal and emergency situations, e.g. in terms of manning, training and qualifications;
d) compliance with mandatory rules and regulations, and other applicable codes and standards, through proper maintenance of structures, systems and equipment (Ref. 27).

5.1.2 1995 Amendments to the STCW Convention

The 1995 amendments to the convention on Standards, Training, Certification and Watchkeeping for Seafarers (STCW 95) (Ref. 25), which came into force on 1st February 1997, have introduced new requirements for seafarers, administrations, training institutions, and shipping companies.

A significant amendment is the introduction of specific standards of competence for seafarers. Additional key elements of STCW 95 relate to simulator training, minimum rest periods, familiarisation training, special training for certain ship types and alternative certification.

The package of amendments identifies three sets of new requirements, covering new responsibilities for shipping companies, new uniform standards of seafarer competence, and new measures to ensure implementation by administrations.

The duty to ensure proper implementation of STCW 95 is placed upon the flag states. These are now directly responsible for the training of seafarers to whom they issue certificates. They can no longer accept the certificates issued by others at face value but must have some system for ensuring confidence that the certificates have some meaning.

The structure of the STCW convention comprises 17 articles, an annex of regulations and a new code. This code is divided in to two parts. Part A contains mandatory requirements and Part B contains recommended guidance.

It is anticipated that a tightening of the training requirements and concentrating upon the operator competency will lead to significant improvements in safety and reduction of error due to inadequately trained seafarers. Such improvements will not, however, happen in isolation of changes to the technical and managerial environment. The most that can be hoped for is that seafarers may be given a level of skill that will prepare them more effectively to deal with novel situations as well as those specifically covered by the training.

5.2 ISM, STCW 95, and Human Factors

It is instructive to consider the relationship between the ISM Code, STCW 95 initiatives, and the field of HF which has been discussed in previous sections of this Paper.

While both the initiatives represent substantial progress in addressing important human element issues, the ISM Code and STCW 95 should not be seen as the total solution to improving human reliability and human performance.

The ISM Code emphasises the role of Safety Management Systems and as such can be seen as providing a mechanism for putting in place the management and organisational controls for ensuring improved levels of safety and environmental protection. The Code is not prescriptive, and as such does not provide the shipowner or operator with the means to identify, or address specific human element issues that may arise in the design and operation of a fleet or specific vessel. The ISM Code is flexible and allows owners or operators to be proactive in addressing specific issues, or problems, which may lead to undesirable consequences in terms of safety or pollution (Ref. 27). It is at the level of more detailed human element issues that the HF methods, models, guidelines and standards that have been discussed in this Paper can be utilised. For example, such issues may be in relation to: the integration and use of particular system on board a vessel; the design and layout of the bridge; an analysis of specific task requirements or specific training needs; or the investigation into the underlying causes of recurring accidents or incidents.

In a similar way, STCW 95 whilst regulating crew responsibilities, training and skills, does not provide the means to assess specific training needs, or specific work organisation requirements. Such assessments can, however be supported by the use of HF methods and guidelines.

While they represent significant progress in addressing the human element, it should be recognised that regulatory initiatives such as ISM and STCW provide only one means of support to the industry in human element problems. There is additional effort to be made in encouraging the appropriate application of HF methods and guidelines. The regulatory authorities and classification societies can take a role in that effort by providing support to the marine industry by setting standards and publishing and disseminating appropriate guidance. Furthermore, the HF discipline itself can play an important role in supporting the regulatory bodies in formulating future standards and guidance in this area. This can be achieved, for example, through applied HF research, and by providing support to the impact assessment of new technology or new working practices.

5.3 IACS Initiatives

IACS has actively supported the inclusion of human element since the outset of IMO initiatives in the human element area. This has been undertaken both in the work of its working parties and by individual member societies.

An initial response to MSC 60 was for the General Policy Group (GPG) to consider the IMO initiative and at GPG37 call for the development of an appropriate policy. This was submitted to the meeting of the IACS council and an ad-hoc group was first established and then reconstituted as a working party. This working party was specifically tasked with looking at the ISM Code and the man-machine interface as a first step to incorporating the human element.

The aim of the working party, in the longer term, is to define a set of integrated services to ship owners by combining the aspects of classification and statutory certification with the implications of the human element and the management of safety. It is proposed that such an integrated approach, putting more emphasis on the human element to improve safety, will assist IACS to maintain its position at the forefront of the technological developments in the maritime industry.

5.4 Government Initiatives

In parallel with the IMO developments, various national administrations have initiated programmes to consider the human element. The most public of these has been the US Coast Guard's 'Prevention through People' (PTP) programme (Ref. 28).

The PTP programme has identified four elements that support safe & profitable operations:

- Management
- Work environment
- Behaviour
- Technology

These elements, it is proposed, require a foundation of appropriate rules, regulations and standards and represent the components that affect human performance.

The PTP programme involves a range of activities, including: joint USCG-industry partnerships and action teams that are tasked to address specific issues (such as reduction in the rate of inland waterway towing fatalities); and USCG sponsored HF seminars and training courses for the marine industry. The PTP programme is continuing to develop this philosophy and it forms the basis of the US input to the work at the IMO.

Other Governments appear to be concentrating on the inclusion of human factors techniques within their accident investigation activities. This commonly involves the development of a specific classification framework, and detailed training of the investigators, so that they can apply and codify the possible causal factors of accidents. Such a practice has been applied successfully within the aircraft industry for several years.

6 LR's On-going Human Element Related Activities

LR is currently engaged in a number of human element related activities and is taking an active part in the IACS working party on the Human Element described earlier. Furthermore, as well as participating in industry initiatives in this area, internally within LR there is an on-going assessment of the field of HF and how it can best be applied in the development and provision of services to LR clients in the future. This Paper represents one output from that on-going assessment. Part of this assessment involves taking due consideration of the development and application of HF in other industries, such as aviation, process control, and offshore. In so doing, LR is able to draw upon both the general experience of those industries, and upon the work of LR's in-house HF specialists who are actively involved in providing services to clients across those sectors.

Below is a brief description of LR's other activities currently being undertaken in the human element area.

6.1 ISM Auditing

LR has developed services to meet the industry's needs in respect of meeting the requirements of the ISM Code. LR is thereby able to provide an ISM certification service to its clients. The method of achieving certification involves the companies in establishing a documented management system. Once established the management system is audited to assess its implementation and level of effectiveness against the declared system and the Code requirements.

6.2 Enhanced NAV1 – Notation 'IBS'

In recognition of the continuing advances in integrated bridge system (IBS) technology, LR has developed an enhanced notation to 'NAV1' with rules governing navigational arrangement for periodic one-man watch (Lloyd's Register of Shipping , Rules and Regulations for the Classification of Ships, Part 7, Chapter 9, Navigational Arrangements for Periodic One Man Watch). The 'NAV1-IBS', introduced in July 1996, includes consideration of the ergonomic issues of efficient information presentation alongside its coverage of the technical aspects associated with the use of the latest IBS techniques and technology.

6.3 ATOMOSII R&D Project

LR is a partner in a collaborative European R&D project, entitled ATOMOSII ('Advanced Technology to Optimise Maritime Operational Safety: Integration and Interface'), investigating integrated ship control systems (ISC). The project is addressing the inter-related issues of safety, efficiency and ergonomics in the context of ISCs. Human factors is seen as a key area within the project and, as

part of the work, a 'Unified Human-Machine Interface' standard for maritime applications is being developed. This will form part of a Conceptual Ship Control Centre Design Standard that will constitute the main output from ATOMOSII.

In developing the standard, the project will run from the definition of user requirements all the way through to prototype implementation, ending with simulator-based validation and an assessment of overall benefits.

Part funded under the EU's Waterborne Transport research (4th Framework) programme, LR is working on ATOMOSII alongside maritime automation companies, ship operators, marine consultancies, research institutes, and universities from across Europe.

7 Summary and Conclusions

This Paper has discussed the growing importance of the discipline of Human Factors within the marine environment. As is being experienced in other industries, increased automation and changes in working practices (e.g. reduction in manning levels) have raised the significance of human over purely technical considerations in the design, construction and operation of complex engineering systems. The uptake of HF is vital in order to support and complement the continued improvements in maritime safety that are afforded by improved reliability of technical components, and enhancements in technical regulation. It is recognised that the diverse and international nature of the shipping industry make a uniform application more difficult and provides a significant challenge to those bodies responsible for enhancing safety.

It is important to stress that HF embodies a set of principles and not merely a set of methods and guidelines. The key to HF principles is the view, derived from the human sciences, that the human is the central component of a work system. In adopting this view, HF can be seen to take a 'human-centred', as opposed to 'technology-centred', view in the design, operation, and future development of engineered systems. Such a viewpoint is very pertinent to today's marine environment.

This Paper has described the inter-disciplinary nature of HF, and has provided an overview of relevant models, methods and guidelines that facilitate the practical and effective consideration of human element issues. In so doing, an aim of the Paper has been to convey an important message: that human element issues are neither 'common sense' nor, conversely, is the undeniably high level of complexity and variability of human behaviour so great that any attempts to address the subject are rendered futile. Furthermore, it is important to go beyond mere recognition of the significance of the human element and to make the identification of practical initiatives in this area an on-going process. A large body of research and practical experience in addressing the human element has been built up and can be called upon by the maritime community, as is being done to varying degrees in other industries. International recognition of the important role that the HF can play alongside traditional marine engineering disciplines is demonstrated, for example by IMO's human element initiatives that have been outlined in the Paper. The potential offered by the application of HF is being addressed to some degree by the initiatives discussed in this Paper. The overall picture, however, is to some degree fragmented with various parties investigating different solutions.

In summary, the primary areas within the marine environment where HF principles, methods and guidelines, are applicable can be summarised as follows:

- advanced technology on-board ship and its impact upon working practices. In the context, for example, of advanced integrated bridge systems, or in advanced machinery control and unmanned machinery spaces.

LR is at the forefront of this area, having recently introduced its 'NAV1-IBS' rules and through its involvement in the ATOMOS-II R&D project.

- Identification and assessment, through the use of human error and human reliability analysis methods, of critical maritime tasks in order to determine measures to reduce the likelihood and impact of human error throughout the ship lifecycle.
- Improved frameworks, utilising human error classifications, for maritime accident and incident analysis and accident data capture, to enable consideration of human element issues and the identification of appropriate improvements.
- Identification of the appropriate 'human element' content of future industry rules, regulations, guidelines and standards. This should be done by adopting a human centred approach to the design and impact assessment of new technology and new working practices, and by learning from and sharing experiences with, other industries.

It is a fact that the world's fleet is becoming increasingly 'hi-tech' in terms of design and building technology, and in operational practices. Many of the systems being developed are based upon implicit assumptions about working practices, and the interface between the human and the technology. Systematic application of HF principles, methods and tools to the development of systems increases the likelihood that safety and human performance issues are properly addressed when introducing new technology and changes in work practices.

LR has an important role to play in increasing the current momentum for human element initiatives in the marine industry. In harnessing its wealth of marine knowledge and expertise with its HF capability, LR is in a leading position to fulfil such an important role in the future.

8 Acknowledgments

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Glossary

ACTIVE ERRORS
Those human errors which lead directly to an unsafe situation.

ANTHROPOMETRY
Branch of ergonomics concerned with the measurement of physical and physiological dimensions of the human body. Used to determine the design requirements of a workspace, in terms of such features as seating, location and viewing angle of displays and controls, and the weight and size limits for manual handling taking into account human strength.

COGNITIVE
The human intellectual capabilities encompassing perception, language, memory, learning and information processing.

ERGONOMICS
Traditionally the part of the Human Factors (HF) discipline concerned with the physical and physiological ("knobs and dials") aspects of system design and evaluation. Now used more commonly as a synonym for Human Factors.

HUMAN CENTRED DESIGN
An approach that focuses specifically on making systems usable and safe for their users.

HUMAN COMPUTER INTERACTION (HCI)
The specification, design and evaluation of the interface between humans and computers.

HUMAN ELEMENT
Human involvement in a work setting, e.g. in bridge operations on-board ship, industrial process control etc.

HUMAN FACTORS (HF)
The discipline, encompassing human sciences and engineering, concerned with the optimisation of the relationship between people, their work activities, and their working environment.

HUMAN RELIABILITY ASSESSMENT (HRA)
Assessment involving qualitative and/or quantitative methods, to determine the likelihood and potential consequences of errors by specified human operators carrying out specified tasks.

INTERACTIVE COMPUTER SYSTEMS
The class of computer systems that involve a high level of exchange of information (dialogue) between a user and the system.

ISM
The International Management Code for the Safe Operation of Ships for Pollution Prevention (Chapter IX of SOLAS).

LATENT ERRORS
Those human or organisational errors that lie within a work organisation and that contribute to, and are revealed by, an unsafe event (i.e. incident or accident).

MEPC
Marine Environmental Protection Committee of IMO.

MSC
Maritime Safety Committee of IMO.

P&I CLUB
Protection and Indemnity Club. Owners mutual (liability) society.

TASK ANALYSIS
A set of HF methods used for representing and understanding the content and sequence of physical and cognitive actions that a person carries out to achieve a system goal.

USABILITY
A quality feature of a computer based system determined by the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals. Often equated with "user-friendliness".

WORK SYSTEM
A system, consisting of users, equipment, tasks and a physical and social environment, for the purpose of achieving particular goals. For example, a ship, its crew, the operations undertaken, and the various ship control systems used in making a voyage can be considered as a work system.

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Appendix A – Description of Task Analysis Techniques

A.1 Task Analysis Techniques

Two of the most significant techniques available and their primary uses are discussed below:

A.1.1 Hierarchical Task Analysis (HTA)

This is the best known task analysis technique. It is used to represent the relationship between tasks and subtasks, recording system requirements or functions, and how these are to be achieved. Plans are also developed along with the hierarchical structure of operations, which enables the technique to record the order in which tasks and subtasks are to be performed.

HTA is often used to develop a framework within which other task analysis techniques are applied. For instance, within the process of carrying out a HTA there are frequently requirements to identify when operations must be done, how quickly they must be done or what sort of difficulties may be incurred. These may be identified by discussion with a task expert, or by simple observation, but it may also be beneficial to adopt another complementary task analysis approach which may be more suited to such data collection.

HTA is a general method which can be applied in all of the application areas discussed above. It is, perhaps, best developed in collaboration between the task analyst and people involved in actual operations, including managers, engineers and other operations staff. It is this collaboration which often provides the strength of the analysis - by ensuring the adequacy and completeness of the information gathered. It is this very same attribute which has led to the Hazard and Operability (HAZOP) study technique being recognised and adopted internationally as one of the most powerful hazard identification techniques.

A.1.2 Task Decomposition (Tabular Task Analysis)

Task decomposition is used to expand upon a basic description of the activities which make up each task element. As such, it requires a set of basic task descriptions, most usually developed from a HTA, as described above. It is often referred to by the term Tabular Task Analysis, which reflects the presentation of the information gathered in the task decomposition process.

The choice of decomposition categories depends entirely upon the purpose of the analysis and the information requirements of the analyst. Often, the information gathered in a task decomposition process is used to determine control and information requirements or to assess the adequacy of control and information provisions. It can, however, be used to meet organisation-specific requirements, for example, by identifying relevant codes of practice or standards applicable to any task or by identifying the safety classification of equipment used.

The information can also form the fundamental basis for design decisions and provide detailed background information for discussion of particular issues. The method provides a structured framework for the gathering of information, whilst remaining flexible in enabling the analyst to develop the information required to address particular issues in as much detail as necessary.

Other Task Analysis Techniques

Examples of other techniques include:

- Charting and network techniques, including operational sequence diagrams;
- Interface surveys, including coding consistency and operator modification surveys;
- Influence diagrams;
- Questionnaires and structured interviews;
- Timeline analysis;
- Walk through/Talk through.

For a detailed review of Task Analysis techniques see Ref. 14.

Appendix B – Example of Hierarchical Task Analysis

(Extract from LR's R&D Project LOADPLANNER.)

Explanation of Figure B.1

The Figure shows an extract of a hierarchical task analysis of the cargo loading task undertaken in the LR R&D project, LOADPLANNER. Each task is represented by a box labelled with the task name, with the most general task labelled at the top of the diagram and the more detailed sub-tasks arranged in levels below. The constituent sub-tasks of a particular task are executed in the order indicated by the key words in the figure, i.e.

- SEQUENCE, in sequence;
- PARALLEL, in any order including interleaved;
- LOOP, iteratively until successfully completed.

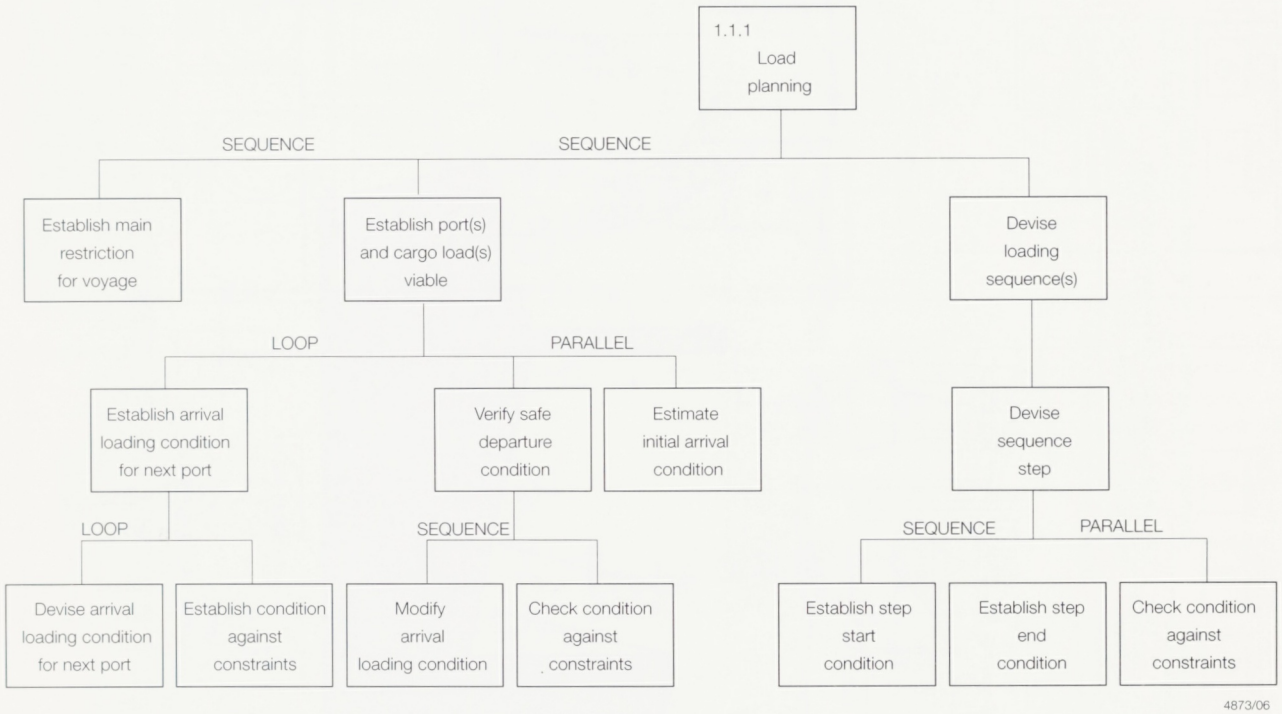


Figure B.1
Hierarchial Task Analysis of Ship Load Planning Operation
(Extract from LR's R&D Project Load Planner)

Appendix C – Examples of Human Factors Guidelines

Examples are given for each interface described in the SHEL Model.

C.1 Liveware – Hardware

See Figure C.1.

C.1.1 Guidelines for Display-control relationships [Original source (Ref. 29)]

For associated displays and controls, the panel layout should make such relationships clear by techniques such as:

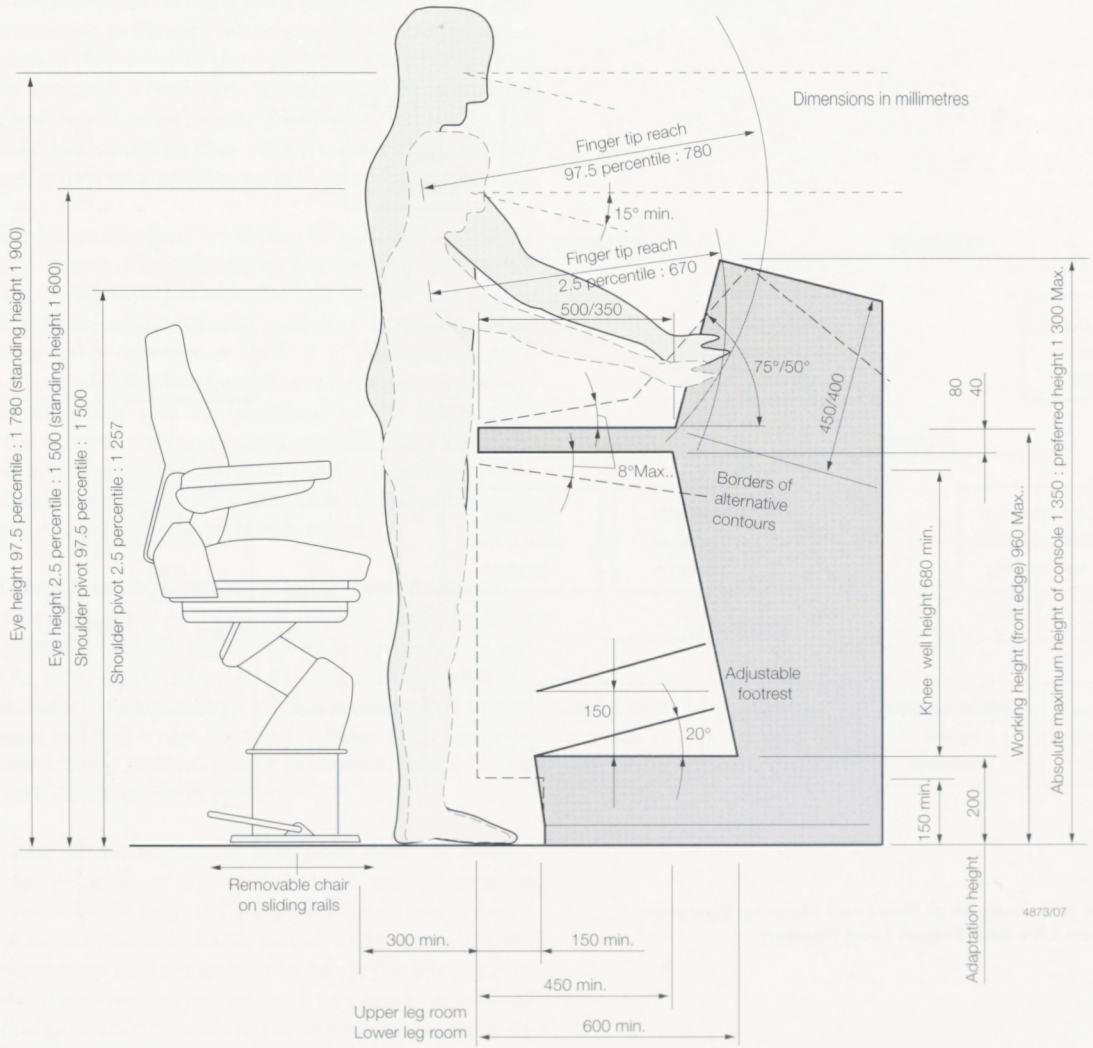
- Adjacent positioning.
- 'Mapping' of controls in a group on to displays in another group.
- Lines and other guides drawn on panels to connect displays and controls.
- Coding devices such as colour, shape, lettering, numbering etc.

Figures C.1.1 (a), (b) and (c), overleaf, demonstrate ways by which control panel design can be improved.

Figure C.1.1(a) Illustrates the initial design.

Figure C.1.1(b) Remedial solution, achieved by appropriate use of emarcation lines and labelling to group instruments together.

Figure C.1.1(c) Retrofit solution. This is a more fundamental re-organisation of the instruments based upon the tasks which have to be done. It should be noted that in this example five of the instruments which were associated with the 'South' side of the system are missing from the retrofit solution. This is because they were moved to an adjacent panel.



Note : The intention of this figure is only to demonstrate solutions based on ergonomic principles

Figure C.1
Anthropometric Data Ranges in Control Console Design [Source ISO 8468:1990]

Figure C.1.1
Remedial and Retrofit Controls [Source (Ref. 29)]

C.2 Liveware – Software

See Figure C.2 Recommended displays for various operator requirements.

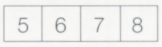
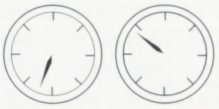
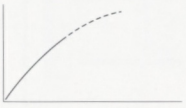
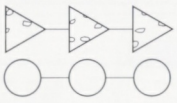
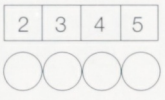
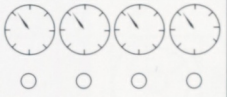
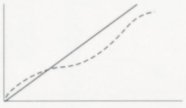
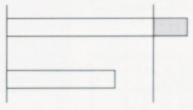
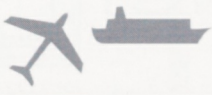
Operator requirement	Preferred display type	Example	Alternative display type	Example	Notes
Precise reading of slowly changing information	Digital		Analogue (quantitative)		Slowly changing information is where the last digit is unlikely to change within 0.5 secs
Precise reading of rapidly changing information	Digital and analogue combination		Analogue qualitative)		
Assessing rate of change	Representational		Analogue (quantitative)		
Single check reading	Analogue (quantitative)		Analogue (qualitative)		Mark safety and danger area
Multiple check reading	Analogue		None		
Warning	Analogue (qualitative)		Representational		Should be accompanied by an auditory alarm. Critical warnings should be Signalled by flashing lights or modulating tones
Extrapolation or prediction	Analogue (quantitative)		None		
Monitoring state	Representational		Analogue (qualitative)		Where appropriate colour should be used to provide additional information
System interactions	Representational		None		
Setting	Digital		Analogue		Settings should be in discrete steps
Trend information	Analogue (quantitative)		Analogue (qualitative)		
Identification codes	Digital	A62 S93	Representational or analogue		4873/09

Figure C.2
Recommended Displays for Various Operator Requirements [Source (Ref. 29)]

Table C.2 Colour of indicator lights and their meaning.

Table C.2
Colours of push buttons and their meanings
[From BS 4099 - Part 1: 1986; taken from (Ref. 29)]

Colour	Meaning of Colour	Typical Applications
RED	Action in case of emergency	Emergency stop Fire fighting
	STOP, or OFF	General stop To stop one or more motors To stop a part of a machine To open a switching device Reset combined with STOP
YELLOW	Intervention	Intervention to suppress abnormal conditions or to avoid unwanted changes
GREEN	START or ON	General start To start one or more motors To start a part of a machine To close a switching device
BLUE		A meaning not covered by the above colours can be allocated to this colour in particular cases
BLACK GREY WHITE		Can be used for any function except for buttons with the sole functions of STOP or OFF

C.3 Liveware – Environment

See Figure C.3 Temperature/Humidity Comfort Envelope.
See Table C.3.1 Lighting (Lux) levels for different tasks and
Table C.3.2 Effects of Noise on Human Performance.

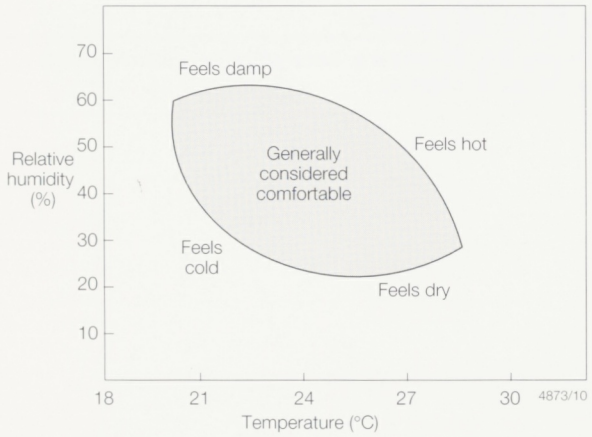


Figure C.3
Comfort Zone as a Function of Relative Humidity Versus Temperature [Source (Ref. 29)]

Table C.3.1
Recommended illumination levels for various operational and maintenance tasks [Source (Ref. 29)]

Task	Suggest Illumination Levels (lux)		
	Preferred	Minimum	Maximum
Control Room Operations			
Viewing hardwired displays and manipulating controls			
Normal lighting	300	200	500
Emergency lighting	300	100	500
Viewing CTR displays			
Shining on CTR	<30	–	50-100
Surround	300	100	500
Reading			
Large print	300	100	–
Small print, or handwritten reports: prolonged reading	700	500	–
Writing and recording data	600	500	1000
Maintenance			
Inspection			
Simple (e.g. check cabling)	300	200	500
Difficult (e.g. logic circuit board inspection)	700	500	1000
Exact (e.g. instrument calibration)	1500	1000	2000
Electrical instrument testing	500	200	–
Repair work			
Instrument replacement	500	300	–
Instrument repair	2000	1000	–

C.4 Liveware – Liveware

C.4.1 Team Responsibility guidelines [from (Ref. 28)]

The allocation of responsibility within teams of workers should be clear.

- In teams, is the allocation of responsibility and authority, clear, complete, non-overlapping, known to, and accepted by, the operators?

For example, when several people work on the same control panel.

- Are the changes in these responsibilities during any emergency clear and practiced?
- Are there clear procedures for the handover of information and responsibility between:
  - different shifts?
  - people with different responsibilities? (e.g. operators and maintenance personnel).
- Is the social situation such that an operator can indicate the errors of others, including superiors, without embarrassment?

Table C.3.2
Effects of Noise on Human Performance [Source (Ref. 31)]

Noise Level, dB	Effects
100	Serious reduction in alertness. Attention lapses occur, although attention duration is usually not affected. Temporary hearing loss occurs if no protection is provided in the region 600 to 1200HZ. Most people will consider this level unacceptable, and 8h is the maximum duration they will accept.
95	Considered to be upper acceptance level for occupied areas where people expect the environment to be noisy. Temporary hearing loss often occurs in the range from 300 to 120HZ. Speech will be extremely difficult, and people will be required to shout, even though they may be talking directly into a listener's ear.
90	At least half of the people in any given group will judge the environment as being too noisy, even though they expect a noisy environment. Some temporary hearing loss in the range from 300 to 1200HZ occurs. Skill errors and mental decrements will be frequent. The annoyance factor is high, and certain physiological changes often occur (for example, the pupils dilate, the blood pressure increases, and the stroke volume of the hear may decrease). Listening to a radio is impossible without good earphones. The maximum duration that most people will accept is 8h.
85	The upper acceptance level (noise expected) in the range from 150 to 1200HZ. Some hearing loss occurs in the range from 300 to 1200HZ. This is considered the upper comfort level, although some cognitive performance decrement can be expected, especially where decision making is necessary.
80	Conversation is difficult (that is, people have to converse in a loud noise less than 1ft apart). It is difficult to think clearly after about 1h. There may be some stomach contraction and an increase in metabolic rate. Strong complaints can be expected from those exposed to this level in confined spaces, and 8h is the maximum duration acceptable within the frequency range from 1200 to 4800HZ.
75	Too noisy for adequate telephone conversation. A raised voice is required for conversant 68cm (2ft) apart. Most people will still judge the environment as being too noisy.
70	The upper level for the normal conversation, even when coversants are close together (at a distance of 1.8m (6ft)) people will have persons such as industrial workers and shipboard personnel who are used to working in a noisy environment will accept this noise level, unprotected telephone conversation will be difficult (upper phone level is 68dB).
65	The acceptance level when people expect a generally noisy environment. Intermittent personal conversation is acceptable. About half of the people in a given population will experience difficulty sleeping.
60	The upper limit for spaces used for dining, social conversation, and sedentary recreational activities. Most people will rate the environment as "good" for general daytime living conditions.
55	The upper acceptance level for spaces where quiet is expected (150 to 2400HZ). People will have to raise their voices slightly to converse over distances greater 2.4m (8ft). This level of noise will awaken about half of a given population about half of the time. It is still annoying to people who are especially sensitive to noise.
50	Acceptable to most people where quiet is expected. About 25% will be awakened to delayed in falling asleep. Normal conversation is possible at distances up to 2.4m (8ft).
40	Very acceptable to all. The recommended upper level for quiet living spaces, although a few people may still have sleep problems.
30	Necessary for specialised listening tasks (for example, threshold signal detection).
Below 30	Introduces additional problems: low-level intermittent sounds become disturbing. Some people have difficulty getting used to the extreme quiet, and a few may become psychologically disturbed.

Appendix D – Clauses of the ISM Code

(The International Management Code for the Safe Operation of Ships and for Pollution Prevention, 1994 Edition).

1. General
2. Safety and environmental-protection policy
3. Company responsibilities and authority
4. Designated person(s)
5. Master's responsibility and authority
6. Resources and personnel
7. Development of plans for shipboard operations
8. Emergency preparedness
9. Reports and analysis of non-conformities, accidents and hazardous occurrences
10. Maintenance of the ship and equipment
11. Documentation
12. Company verification, review and evaluation
13. Certification, verification and control
    Resolution A.741(18)

LR *Technical Association*

Aspects of Maritime Satellite Communications and Radio Surveys

by R. A. Cooper

Lloyd's Register

Paper No **5**
Session 1996–1997

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LR *Technical Association*

Discussion on the Paper

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71 Fenchurch Street, London, EC3M 4BS

Aspects of Maritime Satellite Communications and Radio Surveys

by R. A. Cooper

DISCUSSION

From: Mr. M. I. Blunden

I would like to thank the Author for another excellent Paper which brings the operation of GMDSS thoroughly up-to-date and gives us a glimpse at what might become commonplace for both ship and personal radio-communications in the next millennium.

INMARSAT is central to the success of GMDSS and the developments fostered and brought to fruition by that organisation in its short life have been impressive. Given the current fashion for "privatisation", reflected perhaps in recent developments to change INMARSAT's name to the International Mobile Satellite Organisation and its venture into aeronautical and land-mobile markets, I wonder to what extent the Author would attribute INMARSAT's success to its formation as an international governmental co-operative? Notwithstanding severe cultural and political differences between the major powers of the day, INMARSAT has provided a splendid example of international co-operation and progress. Does the Author consider that this tradition of common achievement will be sustainable under the new order?

Despite the slow rate of conversion to GMDSS for Convention ships, some administrations, including the US and UK, have either withdrawn, or shortly intend to withdraw, existing shore radiotelegraph facilities. Is this too short-sighted; or is it a function of the brave new world of privatisation and its distaste for providing a service which, perhaps by definition, is not profitable?

Vessels continue to be lost and, yacht casualties apart, there seems to be very little evidence that GMDSS equipment actually works in an emergency. Does the Author believe that it would be encouraging to everyone in the maritime radiocommunications industry, and for seafarers in particular, if IMO were to collate examples where GMDSS elements have resulted in vessels and lives being saved – and to promote and publicise these examples vigorously?

To: Mr. M. I. Blunden

Mr Blunden raises interesting issues on which governments' views world-wide have developed over time. Over the past twenty years there would appear to have been a shift in attitude toward the public financing of major projects. Where once governments' attitudes were perhaps amenable to such funding, they seem less so nowadays. World-wide the tendency has increasingly been toward funding by share issue rather than by government. An example is the joint France – UK channel tunnel project, which in previous years would more likely have been a joint government funded project.

Speculation exists as to whether past projects would have come to fruition without government funding. The conventional wisdom is that the France – UK Concorde passenger aircraft would never have been produced had it been left entirely to share holder funding. One's view on whether this would have been for better or worse is up to one's personal view on these matters. Having flown Concorde a number of times, my view is that it would have been a great pity if it had never been built, although I tend to the opposite view when wind conditions are such that its take off flight path is over my house!

Technological and commercial pressures would almost certainly have resulted in an INMARSAT type of service emerging whether or not government funding had been made available. However, without initial government funding the service would almost certainly not have become operational as early as it did. A contra view pointing to the fact that Marisat, the first maritime satellite service (Section 1.4 of the LRTA Paper refers) is run by COMSAT General (a US shareholder owned organisation), is not valid, in view that it utilised spare satellite capacity made available by the US Navy which, by any other description, is government funded.

Funding apart, without widespread governments' endorsement of INMARSAT, the IMO view that competing systems would have emerged (Section 2.1 of the LRTA Paper refers) has strength. It is a moot point as to whether competition in the context of a global maritime satellite service, offering government funded distress and safety facilities would be of overall benefit to the maritime community. Certainly it was a situation on which, at the time INMARSAT was set up, IMO held firm views (Section 2.1 of the LRTA Paper refers).

With the passage of time and with diversification into other mobile satellite services, INMARSAT is, at a date yet to be agreed, to become a shareholder owned organisation. This has not been driven by the maritime services for which it

was originally set up, but it will encompass these services. As far as competition is concerned, IMO will most certainly seek assurances that measures are in place for the continued funding by governments of existing global distress and safety services.

INMARSAT, particularly in respect of its maritime services facility, is nothing without international co-operation. One assumes that the term "governmental co-operative" will wither on the vine when share ownership becomes a reality along with "a not for profit organisation" as it once described itself. The jury is out on the matter of whether INMARSAT's past tradition of common achievement will be sustainable under the new order, however, the verdict will be heavily influenced by the way in which the legislative framework is set. Much of the burden is on IMO to ensure that this legislative framework will meet the needs of seafarers. Given the will, the desired result is achievable as is evidenced by the emergency public telephone services in the UK which are as available under share ownership companies as they previously were under the GPO as a UK Government department.

INMARSAT's name change from the "International Maritime Satellite Organisation" to the "International Mobile Satellite Organisation" (albeit retaining the familiar acronym) reflects the diversification of the organisation's activities and came before the issue of share ownership was mooted. The name change was driven by technology and a commercial realisation that the organisation needed to diversify into other satellite mobile markets. Not to do so would have eventually posed a threat to INMARSAT's maritime services from the emerging mobile satellite service providers.

A justification for those governments, including the US and UK, which have either withdrawn or contemplated withdrawing the coastal maritime radiotelegraphy facilities, such as the distress watch on 500kHz, would no doubt be the statutory requirement since 1st August, 1993, to have on board a satellite EPIRB, thereby facilitating global distress alerting; albeit from one single means and from one single piece of equipment! Nevertheless, the withdrawal of shore based radiotelegraphy services prior to 1st February, 1999, (if not 1st February, 2001, in view of the provision in SOLAS) does not rest easily with the spirit of intent implicit in the 1988 amendments to SOLAS to which contracting governments put their names.

The decision to dispense with radiotelegraphy services in the UK cannot reasonably be attributed to privatisation. As far back as I can recall, services provided by BT/PO/GPO for Government departments have been funded by the particular Government Department concerned. The decision to cease the radiotelegraphy distress watch in the UK was made by Government, and would have been taken whether or not the service provider, BT in this case, was a shareholder owned company.

With respect to the lack of good hard statistics which demonstrate the benefit or otherwise of GMDSS, I have little doubt that it would be most encouraging to everyone in the maritime radiocommunications industry, seafarers and IMO alike, to have statistics which indicated that most of the equipment works most of the time. By the same token, it would be most depressing to all concerned if such statistics indicated that the opposite was the case! The only statistics which various entities seem able to produce are those which show that the vast majority of distress alerts are false (Section 7.2 of the LRTA Paper refers) seemingly demonstrating appalling operating standards.

The problem with IMO collating the statistics would be their vested interest. If in doing so IMO demonstrated the good worth of GMDSS, they would inevitably open themselves up to ridicule with "they would say that wouldn't they" type comments, not to mention criticism in allocating scarce resources to promote themselves. Conversely, is it really credible that any IMO generated and collated data would produce evidence to demonstrate anything other than the good worth of GMDSS, a system which they devised? Any examination into the benefit or otherwise of GMDSS would have to be conducted by an independent body with no vested interest in the results. As to who that body should be (a classification society?) and more importantly, how such an exercise would be funded would need to be addressed.

Mr Blunden's contribution is much appreciated.

From: Mr. R. Moore

I should like to congratulate the Author on an interesting and well presented Paper.

Although the Paper is mainly concerned with fixed shipboard installations, mention has been made of hand held equipment such as mobile phones. We see these phones about us in everyday use and I am becoming increasingly aware of various restrictions being imposed on their use. Could the Author please comment on the technical reasons behind the following restrictions:

(i) Aircraft: the use of mobile phones is prohibited during flights.
(ii) Petrol Station Forecourts: there are notices displayed to the effect that mobile phones must be switched off whilst filling the tank.
(iii) Conference Halls: IMO meetings, etc., delegates are requested to switch off mobile phones to avoid interference with the microphones and the continuous translation service.

Furthermore, are problems foreseen with interference between such hand held equipment and essential shipboard systems? Are there any mobile phones suitable for use in hazardous locations such as tanker decks and cargo pump rooms?

To: Mr. R. Moore

Mr Moore raises one of the most challenging problem areas in electro-mechanical and electronic design, which is pertinent to broad areas of technology, and comes under the standard descriptive phrase of "Electro Magnetic Compatibility" (EMC). This is touched upon in Section 4.6 of the LRTA Paper.

We have probably all experienced at some time in the past interference on our domestic radio or television caused by, perhaps, an enthusiastic DIY neighbour's electric drill with a grubby scarred commutator, or their son's old banger with poorly suppressed economy sparking plugs. These are examples of poor EMC which are easy to identify and resolve. Other examples are less so, or perhaps not worth the effort to resolve. For example, a momentary flash across the TV screen can often be attributed to a household thermostat (yours or a neighbour's) which although easy to resolve, because of the minimal disturbance it causes, is often tolerated.

All EMC failures are capable of being addressed by the introduction of circuitry consisting of coils and capacitors. These trap or filter out the electrical impulses which cause the interference. Often, manufacturers of electrical equipment are aware of a potential EMC difficulty but, for sound commercial reasons, do not install the required circuitry because of the low probability of the problem arising. A personal example of this was a new burglar alarm installed by my neighbour which was activated whenever I transmitted on certain bands from my amateur radio station.

The problem was not my radio equipment, but rather inadequate EMC of my neighbour's burglar alarm circuitry. The matter was easily resolved by the manufacturer who installed a tiny piece of circuitry in my neighbour's alarm system which acts as a filter for the spurious electrical pulse which would activate the alarm. The manufacturer was aware of the potential problem, but took the commercial decision not to install the filter in their product because of the likelihood that few of their customers would be unfortunate enough to have a neighbour who operates an amateur radio station. However, in the isolated occasion where this did occur, the manufacturer provided the means to resolve the problem.

Perfect EMC can seldom be achieved. This is because of changing technology. The best that can be done is to manufacture equipment with immunity from extraneous electro mechanical influences known at that point in time. Hence, a piece of equipment manufactured last year with complete immunity from all known EMC problems does not mean that such problems will not arise when it comes into close proximity with equipment manufactured this year!

What obviously cannot be tolerated is risk to life and limb caused by poor EMC. The operation of mobile phones, as well as computer games and similar gadgets, are prohibited inside aircraft. This is a precaution against the possibility of inadequate EMC with the aircraft's mass of electronic gadgetry, and the possible catastrophic consequences which could result from electronic interference. It has already been speculated that the tragic loss last year of the TWA 747 passenger aircraft which took off from New York destined for France, may have resulted from a passenger's electrical gadget causing a malfunction in the aircraft's electronic control equipment, due to inadequate EMC. We will probably never know if this was the case. A blanket prohibition on the use of electronic gadgetry is as sure a way of avoiding a potential EMC problem arising as will ever be achieved. Few would argue that, for passenger aircraft, such a policy is anything other than a wise precaution; although I would not be surprised if at some future date market forces demanded "aircraft friendly" mobile phone type approval.

In the case of a petrol station forecourt, there may be a perceived risk to life and limb with the presence of large amounts of highly flammable material. However, the requirement to switch off mobile phones is more likely to be commercially driven to avoid the remote possibility of interference with petrol pump electronic charging mechanisms.

With respect to conference halls and the likes of IMO meetings, the requirement to disable mobile telecommunications apparatus is primarily driven by the distraction caused when this equipment is triggered. To give the reason as the avoidance of interference with microphones and to the continuous translation service is no less than tacit acceptance by the conference hall management that their facilities have inadequate immunity to low level extraneous electro-magnetic influences from type approved telecommunications apparatus.

On board ships, the potential similarly exists with respect to interference with microphones and public address systems. Again, the source of the problem is almost invariably inadequate immunity within these systems, rather than the mobile transmitter apparatus. However, added precautions can be imposed in certain situations, as indicated earlier. Ship hazardous areas often additionally require any equipment with an electrical component, not just mobile phones, to be "intrinsically safe", in other words, to have additional circuitry in the form of coils and capacitors which suppress extraneous emissions more stringently.

In respect of the statutory safety equipment requirement for hand held VHF radiotelephones, intrinsically safe items are available on the market. The effects of this on the equipment is twofold; it adds to its cost and potentially reduces the equipments' operational effectiveness. As with so many safety related matters, it is all a question of balance, with complete suppression of all extraneous effects not being an option as this would render the equipment inoperable!

I should like to thank Mr Moore for his most pertinent question on what can be a complex subject.

From: Mr. A. B. Merchant

I would like to thank the Author for a very good Paper and an excellent presentation. Like his previous Paper, this will also be of great use to all, and most likely form a reference work, especially for field surveyors .

The Author stated that LR did not bid for the MSA tender for Radio Surveys. On the basis that we conduct such surveys on behalf of so many national administrations, can you clarify the reasons behind this decision? Furthermore, do you think it may affect our prospects in this field?

To: Mr. A. B. Merchant

I assume that LR's lack of interest meant that it did not want the business! Such a trite answer is not deserving of Mr Merchant's excellent question. Before answering this question, the following background on the subject is warranted.

From the time when it became a statutory requirement until 30th September, 1996, BT and its predecessor organisations always had the monopoly for the conduct of radio surveys on British Flag ships in the UK. The reason is principally historic. The ultimate statutory responsibility for ships lay with flags' governments and in the days when the GPO was a UK Government Department of State, which encompassed telecommunications issues, it was reasonable that the GPO should assume responsibility in the UK for radio installations on ships. With the passage of time, and the separation of the GPO into postal and telecommunications entities, followed by its creation into a public corporation and ultimately the privatisation of the telecommunications element with its core business activities being eventually opened up to competition, many of BT's former governmental responsibilities were whittled away, with the Government taking many of them over. These have mainly now been devolved to agencies of government, principally the MSA and the Radio-communications Agency.

With the sort of political climatic trend indicated above, BT's continued unchallenged monopoly in respect of statutory radio work on British Flag ships in the UK did not bear close scrutiny and, inevitably, the Government duly announced in 1991 that the matter would be addressed, but in the meantime BT would continue to be used for the following five years. The surprise was not in the announcement itself, but rather the length of time it took to make the decision to address the matter. One can only speculate on the reason for the apparent prevarication. It could have been forces within the industry and Civil Service which saw the combination of BT's competence and, importantly, independence, as assets which could not be easily replicated, other than by classification societies. However, rather than devolving the work direct to classification societies, the MSA took the decision in 1996 to leave the door open for BT by putting the work out for tender. Those who expressed an interest included, of course, BT, most of the ship radio survey companies in the UK and a couple of classification societies – but not LR. The closing date for bids was extended by three months to allow further time for interested parties to put their cases together. The MSA duly announced at the end of September, 1996 that a five year contract had been awarded to GEC-Marconi, effective from 1st October, 1996.

The decision was pretty well universally condemned within the industry, perhaps somewhat disingenuously by other ship radio survey companies, and ship owners through the Chamber of Shipping. There was much critical comment of the decision in the maritime press. The main focus of the criticism was the question mark over GEC-Marconi's independence in its role as both a radio inspector and radio equipment supplier. The assurances of "Chinese Walls" between these two operations within the GEC-Marconi conglomerate seemingly cut little ice.

One thing is for sure, the aspersions voiced with regard to independence could not be levelled at BT which has never had any involvement in ship radio equipment manufacture or supply and, I understand, has no planned intention in this market segment. The same applies to classification societies. Proposals previously made to enable LR to add the UK to the long list of administrations on whose behalf the Society carries out radio surveys have come to nought.

So, coming back to Mr Merchant's pertinent question, I reiterate my opening comment. I assume that the reason why LR has not given anything other than scant consideration to pursuing the possibility of carrying out radio surveys on UK flag ships is that the Society does not want the business. Whether this stance will change when the contract comes up for review in 2001 is open to speculation. One thing is for sure, BT will not be in a position to bid for the work. Their ship radio inspection service has been wound up and all the staff on that function have either been re-deployed or made redundant. Mostly, it has been the latter.

Mr Merchant's contribution on a most pertinent topic is much appreciated.

From: Mr. D. P. Keogh

As the Author is aware, there are currently four satellites used by INMARSAT for global coverage, whilst three would suffice. Is the use of a fourth satellite justified on the grounds of redundancy?

To: Mr. D. P. Keogh

Mr Keogh's question is much appreciated. It touches on the delicate balance between meeting the wishes of the Coast Earth Station (CES) operators whilst containing costs; all underlaid by the INMARSAT organisation's once undeclared aspirations which have since come to fruition.

Global coverage of the INMARSAT facility is provided by four satellite footprints which overlap to a considerable extent (Section 2.3 of the LRTA Paper refers). However, full coverage of all sea areas could equally be achieved by three satellite footprints. Indeed, the deployment inherited by INMARSAT from the Marisat service on 1st February, 1982, was three footprints. Until then there were only three CES operators: two in the US operated by COMSAT General serving the Atlantic from the east coast and the Pacific from the west coast, and one in Japan serving the Indian Ocean.

On the day that INMARSAT became operational a few additional CESs were scheduled to open up for service, one of which was in Kuwait. INMARSAT were anxious to do all they could to encourage the inauguration of CESs and in this respect acceded to the Kuwait operator's preference to have access to the Atlantic with its higher density of maritime communications traffic, rather than the Indian Ocean. The corollary of this was that the Atlantic footprint had to come more to the east than would otherwise have been necessary, depriving coverage in the west and so leaving a small gap off the west coast of South and Central

America. INMARSAT's conventional wisdom at the time was that this was a compromise worth accepting on the basis that it met the perceived needs of an early entry CES operator (Kuwait) and that the additional traffic gained by double coverage from the Atlantic and Indian Ocean footprints over the Mediterranean would more than compensate for the scant traffic potential off the west coast of South and Central America. It was also perceived that once the Saudi Arabia CES opened, which lay further to the west, it would serve the Atlantic footprint and Kuwait, the Indian footprint as part of a traffic sharing arrangement to be shifted slightly to the west which would achieve full sea area coverage.

When the Saudi Arabia CES came into operation it was pointed at the Indian Ocean satellite and Kuwait continued to serve the Atlantic. There was much protracted debate in the INMARSAT Council on why this should have arisen, so preventing the closing of the gap in the South Pacific to provide full sea coverage with three footprints. It was a matter that the INMARSAT directorate chose not to address with much vigour advocating the very high cost alternative of launching additional satellites to provide a fourth footprint. It later emerged that in pursuing this course the Directorate were addressing their own, as yet undeclared, agenda. This was diversification beyond the maritime market into land based operations as, 'coincidentally', a fourth footprint configuration would not only close the South Pacific 'gap', but would also provide coverage over all land areas, which a three footprint scenario could never achieve. The INMARSAT Directorate's stance eventually won over the majority view in the INMARSAT Council, attracted no doubt by the additional revenue earning potential from a new land based market.

Therefore, in summary, whilst three footprints are sufficient to cater for the shipping market, INMARSAT's diversification into the non maritime sector necessitated the provision of a fourth footprint.

From: Mr. A. M. Anderson (LR-Ulsan)

I would like to congratulate the Author on producing a second Paper on a much neglected subject which I am sure will be as useful as his previous Paper. The fact that very little duplication of information occurs between the two Papers only highlights the importance of this Paper to supplement what was said before.

My first question concerns the confusion over boxes 2.6, 2.7 and 2.8 when completing Form 'R' for Radiotelephone/Radiotelegraph installations on ships built before 1st February, 1992. The Author states in paragraph 6.11.1 of his Paper, and in fact is quite adamant, that these boxes should not be completed, quoting the requirements as saying (in Chapter IV, Regulation 1, Paragraphs 5.1.1. and 5.1.2. of SOLAS 1974 with 1988 ammendments) that the vessel should either comply with the amendments, or the requirements prior to the amendments.

The confusion appears to arise over amendments to Chapter III and V of SOLAS 1974 introduced in the 1988 Amendments to SOLAS 1974 (the full title for which is 'Amendments to the 1974 SOLAS Convention concerning Radiocommunications for the Global Maritime Distress and Safety System'). These amendments to Reg. III/6 and V/12 came into force for existing ships on 1st February, 1995, and are listed in the MDSPM, Part E, Chapter 7, Table E.7.5.1, 'Timescale for compliance with GMDSS Regulations'. Could the Author please clarify where these regulations fit into the framework of the GMDSS?

My next question relates to the new INMARSAT-3 service unveiled with a great fanfare in January, 1997. With five of the INMARSAT-3 satellites rather than the present four shown in Figure 5 of the LRTA Paper, what will the coverage be when these are fully deployed? I would also be interested to learn whether INMARSAT-E is a new service, or an upgrade of an existing service, and what, if any, extra benefits it provides?

Finally, I would like to say that the Paper is full of the advantages of the recent developments in satellite communications technology. Is the Author aware of any disadvantages (excluding the employment prospects of qualified radio operators)? As an example, I would ask whether there is over reliance on single links in the communications, e.g. at the satellite or at the Coast Earth Station?

To: Mr. A. M. Anderson (LR-Ulsan)

I should like to thank Mr Anderson for his kind comments. I am pleased that he found the Paper as useful as my earlier one. The points he raises are all highly relevant and I hope the following explanations will be helpful to him as well as surveyors in all LR port offices.

Concerning the completion of Form 'R' in respect of ships installed with a radiotelephony or radiotelegraphy station, in particular Sections 2.6, 2.7 and 2.8, the date of 1st February, 1992, as mentioned by Mr Anderson, was when the GMDSS was implemented and marks the beginning of the seven year transition period, during which all ships with a keel laid date prior to 1st February, 1995, must be installed with a GMDSS radio station. Ships with a keel laid on or after 1st February, 1995, are required to have a GMDSS radio station at the outset. Hence, the question relates to ships built before 1st February, 1995, rather than 1992.

The attachment of Form 'R' (Form 2131) to the radio certificate is a composite design to cater for ships with radio stations in compliance with the requirements both after and before the 1988 amendments. This is necessary because ships may comply with one or the other until 1st February, 1999, by which date the 1988 amendments will be obligatory for all ships. The principle relating to the completion of all Sections in Form 'R' in respect of ships with a radiotelephony or radiotelegraphy station is applicable throughout, but as Mr Anderson says, for some reason confusion generally centres around boxes 2.6, 2.7 and 2.8. This confusion has not been helped by misunderstandings by some administrations. My "adamant" phrasing in the text of the second paragraph of Section 6.11.1 was deliberate for that reason.

A careful reading of the third paragraph of Mr Anderson's contribution provides the answer to his question. Chapter

III and V of SOLAS relate to Life Saving Appliances (LSA) and Safety of Navigation issues which are pertinent to the safety equipment certification process. Radio issues are addressed in Chapter IV, the 1988 amendments of which relate to ships with a GMDSS radio installation. Hence, the requirements in respect of Form 'R' Sections 2.6 (ship's radar transponder) and 2.7 and 2.8 (2128 kHz equipment) are not applicable in respect of a ship with a radiotelephony or radiotelegraphy installation. These requirements are catered for respectively by the safety equipment certification process and Chapter IV prior to the 1988 amendments. The key thing to remember is that the 1988 amendments have no relevance on radio matters where a radiotelephony or radiotelegraphy station is installed except, in respect of the NAVTEX receiver and satellite EPIRB which are applicable to all ships; hence, the requirement for entries at Sections 2.3.1 and 2.4.1 or 2.4.2 (almost invariably the former) on all Form 'R's.

As the title of the 1988 amendments indicate, they are in respect of radiocommunications for the GMDSS. However, it does not follow that the amendments all relate to the radio certification process. The two-way VHF radiotelephones (Reg. III/6) is in respect of the LSA safety equipment certification process, notwithstanding that their functionality is required to be verified at the radio survey (Note 2.2 on the Radio Certificate refers). The same applies to the radar transponders requirement (Reg. III/6), although one of these is also a requirement of the radio certification process for a ship with a GMDSS radio station (1988 amendments Reg. IV/7/1.3 refers). It is to be noted that this radar transponder requirement is not in respect of the radiotelephony and radiotelegraphy certification process although, as with the two-way VHF radiotelephones, their functionality is required to be verified at a radio survey.

The amendments to Reg. V/12 relate to radiocommunications insofar that prior to 1st February, 1992, it formed part of the radio certification process. It will be noted that the amendments make no reference to provisions contained in Chapter IV as previously was the case. As far as the timescales in the MDSPM, Part E, Chapter 7, Table E.7.5.1 are concerned, to which Mr Anderson refers, these relate to the GMDSS requirements overall in respect of both the safety equipment and radio certification processes.

The satellite footprint coverage with the INMARSAT-3 deployment is exactly the same as it was under INMARSAT-2. The fifth satellite is provided for back up purposes. The same situation obtained under the previous deployment.

With regard to the INMARSAT-E service to which Mr Anderson referred. This is an EPIRB facility provided as an alternative offering to the COSPAS-SARSAT, 406 MHz service. It will be noted at Section 2.4.2 of the Form 'R' attachment to the radio certificate, that reference to an INMARSAT satellite EPIRB is made; this is also the case in the documentation relating to the radio checklists records: Forms 2115, 2116, 2137 and 2138. The INMARSAT EPIRB is not one of the INMARSAT Organisation's success stories. The whole project has been dogged with delay from the outset. Before I joined LR, over six years ago, I attended numerous meetings on the INMARSAT EPIRB project, including presentations at the Dornier factory in Germany who, with the backing of INMARSAT, were making the running in their manufacture. To my knowledge, trials of the INMARSAT EPIRB were being conducted some fifteen years ago, and probably prior to that.

I understand that the INMARSAT-E service has only been up and running for the past year, and I am not aware of any ships which have INMARSAT EPIRBs on board. The inordinate delay in implementing the service seems to have been caused by difficulties in setting up the ground stations for the service. In the meantime, the COSPAS-SARSAT, 406 MHz, EPIRB has established such a hold on the market that it will take a long time, in my judgement, for the INMARSAT-E facility to make any significant inroads.

With respect to the final part of Mr Anderson's contributions, I did not particularly set out to fill my Paper with the advantages of recent developments in satellite communications technology. If the Paper reads like that, then perhaps the sorry tale of INMARSAT's foray into the EPIRB service relayed above will go some way to redress the balance.

The fact of the matter is, however, that for long range communications the quality, reliability and speed of connection with satellite communications bears no comparison with morse code transmission. The physics of radio transmission is such that signal paths travel in a straight line. This is all very fine when the transmitter and receiver are in line of sight. For long range communication, where the transmitter and receiver are not in line of sight, i.e. due to the curvature of the earth, difficulties arise. In the satellite service it is a simple matter of line of sight transmissions up to and down from the satellite. The alternative to satellite communications for long range radio transmission for ships, is in the High Frequency (HF) bands which rely on transmitted signals being bounced around the earth's curvature between the ionosphere and the earth. As a general rule it is one of the quirks of physics that the facility to bounce signals in this way only applies in the HF bands. Long wave transmission has the facility to follow the curvature of the earth (ground wave) but requires big aerial constructions and high power, such that it is only suitable for the likes of the BBC overseas service and Voice of America.

One does not have to be a physicist to have an intuitive appreciation that terrestrial signals bounced between the ionosphere and the earth will wax and wane in strength and frequently fade out altogether. This situation is exacerbated by the variable density of the ionosphere which changes according to the time of day, month of year as well as other cyclic factors over a number of years, all of which affect the quality of the transmitted signal. The limitations of long range terrestrial radiocommunications are such that under SOLAS 1974 prior to the 1988 amendments, the range requirement of the main transmitter is 150 miles. Thus, ships with radio stations in compliance with these requirements (currently over half of cargo ships classed with LR) can spend long stretches on the high sea without any form of communications with the shore other than by means of the EPIRB alert facility, which itself only became a requirement in August, 1993.

Ship radio station requirements prior to the 1988 amendments are a reflection of radiocommunications technology available when the 1960 SOLAS was replaced by the 1974 Convention. The 1988 amendments to the 1974 Convention merely exploit the capabilities of the available new technology. Thus, for a ship which sails beyond the range of an MF shore radio station, the minimum range requirements of 150 and 100 miles for the main and reserve transmitters respectively, have been replaced by requirements to have a primary and secondary global distress alert facilities as well as some form of equipment duplication. For the most part, the duplication requirement includes the provision of equipment with global distress alert facilities in addition to the primary and secondary requirement. The 1988 amendments dispense with the arbitrary separation of ship radio station requirements for ships below 1600 GRT and those of 1600 GRT or more, so acknowledging the reality that a ship's safety radio requirements relate to the waters in which she sails rather than her size.

Reliance on radio path links is an inevitable feature of any radiocommunications system. No man-made system of which I am aware has ever been perfect. In the case of the GMDSS, radio links for long range distress alerts are likely to be threefold: Digital Selective Calling (DSC) in the HF spectrum, 1.6 GHz in the INMARSAT service and 406 MHz in the COSPAS-SARSAT system. Where HF DSC does not form part of the on board system, there will be two INMARSAT systems and one COSPAS-SARSAT system.

Any anxieties I have with the GMDSS system relate more to the on board equipment than any inadequacy in the redundancy of the communications links. During the various meetings I attended with shipping interests and radio equipment companies in the lead up to the introduction of GMDSS, a great deal of emphasis was placed on the minimum number of items of GMDSS equipment needed on board, with the implication that any self respecting ship owner would invariably equip in excess of this requirement. The reality has turned out differently with practically all ships being installed with the bare minimum to meet the SOLAS requirements. Indeed, dispensations from administrations to sail without an EPIRB to allow the coding to be updated ashore are not uncommon. In this respect, Tony Bullimore, who was recently rescued from his capsized yacht by the Australian Navy, was better equipped with two EPIRBs than practically any merchant ship.

Of even greater concern, in my view, is the lack of consistency in operating procedures between different equipment manufacturers. It seems unreasonable that a deck officer, whose primary concern is the steering of the ship, should be expected to familiarise himself with different radiocommunications operating procedures depending upon the make of the equipment on board. The present multiplicity in operating procedures and software configurations between different makes of equipment is fertile ground, on which the seeds of a major sea disaster are waiting to be sown. It is a matter which, in my view, needs to be urgently addressed by IMO.

The points raised in Mr Anderson's questions are most relevant and are greatly appreciated.

From: Mr. H. J. Arnold (LR-Fremantle)

The Author has clarified many points on the subject of Radio Surveys, and is to be congratulated not only on the publication of this Paper, but also on his previous LRTA Paper.

With regard to this Paper, the following comments are offered:

Page 19, Clause 6.2, (final sentence)
It is noted at Section 2.2 of Form 'R' that, for a GMDSS survey, the Author is advocating the description of the secondary means of alerting, with appropriate entries, other than the word "YES". This is indeed valuable, and the Radio Surveyor who undertakes such surveys on our behalf has been instructed to provide such an appropriate description in future when reporting GMDSS.

Page 20, Clause 6.5.4 'Liberia'
It appears unfortunate that the Liberian authorities continue to stipulate that a conditional Radio Certificate may be issued valid for three months. For the sake of conformity with other "Conditional Issue" certificates on behalf of the Liberian and other authorities, it would have been preferable if this was limited to two months, but obviously the Liberian authorities have their reasons for allowing a three month Safety Radio Short Term (SRST) certificate. Would it not be possible to encourage the Liberians to re-think, with a view to limiting the SRST, in this particular instance, to two months? It certainly would assist where conformity is concerned, and avoid the unnecessary re-issuing of SRSTs in the future, as errors are bound to occur, either when the Surveyor drafts the certificate, or when the printed certificate is presented for signature to the Surveyor.

Page 23, Clause 6.11.2, (second paragraph re: Clause 6.6.3)
The Author's comment that this should be "one" is noted. Would it be possible to educate those other administrators referenced in Clause 6.6.3 who make distinctions, and in some cases require two qualified operators?

Whilst advocating only one qualified operator, what back-up would there be when that specific person falls ill, or in a state of frenzy falls overboard, attached to an unpadlocked EPIRB?

To: Mr. H. J. Arnold (LR-Fremantle)

Mr. Arnold's comments on both this Paper and my previous one are much appreciated.

Regarding the initial comment, the change in the 'actual provision' description in Section 2.2 of the Form 'R' attachment to the radio certificate, to which reference is made at Section 6.2 of the Paper, emerged from IMO as a result of discussions they had following the loss of the "Estonia" when, seemingly, it was felt that a statement of the actual means of secondary alerting was more appropriate than merely an affirmation that such a means is provided. It is not really a matter of my advocating one way or the other. If it were, then I would advocate a number of measures. One would be to have the 'actual provision' column mean what it actually says – the actual provision of

each item on board, with another column to indicate the statutory minimum requirement. I would also advocate, if it were in my power to do so, that statutory certificates with their attachments be on open display by notice board on the ship. In this way, crew and passengers would be able to note what the ship owner has actually provided against the minimum requirements. Thus, everyone on board could be aware how equipment provision matches up to the statutory requirement, the status of the statutory certificates in respect of validity, as well as applicable conditions and exemptions.

It is difficult to see how 'good' shipowners could possibly have an objection to such a proposal. In my previous employment, prior to coming to LR, I had reasonable scope to input to IMO on matters relating to the interests of the organisation for which I then worked. However, as far as classification societies are concerned, it seems to me that interests, such as the peace of mind of crew and passengers in respect of whether ships' statutory requirements are met, are more difficult to input to IMO.

With respect to the Liberian requirement for radio certificates of competence, as raised by Mr. Arnold, to which reference is made in Section 6.6.3 of the LRTA Paper, I conclude that the reason why the International Registries Inc. stipulate on behalf of the Liberian (as well as the Marshall Islands) Administration three months duration for a statutory radio certificate where the certificate of competence has not been issued by that Administration, is because they have found that it takes that length of time to get the necessary documentation issued and placed on board. These requirements, as well as those of the Panama Administration, have nothing to do with SOLAS which merely stipulates that the radio station must be manned by qualified staff, without any reference being made to the certificate of radio qualification flag administration. Presumably, the three month stipulation is applied by all classification societies which carry out radio surveys in respect of the Liberian Administration. Hence, any "encouragement" on International Registries Inc. to reduce the period would need to be done in concert with other classification societies, presumably through IACS. Such a change would likely register low in the scale of priorities for IACS.

Furthermore, the reduction to two months, advocated by Mr Arnold, would not bring conformity with other conditional statutory certificates. The requirement in this respect is that, in the event of items of a minor nature remaining outstanding due to required services or replacement equipment not being available locally, a conditional certificate may be issued (except in the case of a ship under the Malta Flag) to allow the ship to get to the next port where an exclusive LR surveyor is in attendance (MDSPM, Part E, Chapter 7, Section 5.2.2.1(b) refers). When the issue of a conditional certificate is appropriate, a validity period of two months should not be granted as a matter of course, but rather as the maximum allowable. Thus, in this context the reduction to two months for a conditional certificate to meet the International Registries Inc. requirement would be no less arbitrary than three months, and arguably more so in view of the likely difficulty in getting the certificates of competence on board in the given timescale.

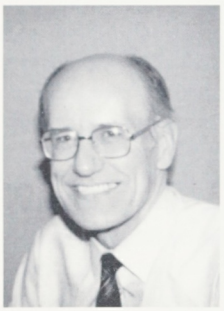
With regard to the number of qualified radio operators required on a ship with a GMDSS radio installation, again administrations' requirements in this respect are not applicable to LR alone, but all classification societies. Interpretation of SOLAS requirements is a fraught business and in consideration of the varied interpretations indicated at Section 6.6.3 of the LRTA Paper, I am not optimistic in being able to persuade all parties as to the correctness of the LR view, even assuming that IACS felt inclined to address the matter.

With respect to the one operator requirement, again it is not a matter of my advocating one preference against another, but rather interpretation from SOLAS. As with equipment provision, one certificated operator is the minimum requirement. GMDSS radio operator certification now forms part of the deck officer training at maritime colleges in the UK and this will almost certainly apply in respect of other flag administrations. Thus, in the fullness of time all deck officers will be certificated in GMDSS radio operation as a matter of course. Having just one certificated operator on board should not imply that a non certificated person is barred from using the radio for day to day communications. The requirement is that there must a designated person on board with the appropriate certificate of qualification who has primary responsibility for radiocommunications during distress incidents.

Mr Arnold's pertinent point about what happens in the event of there being only one such person, who was not available at the critical time, is in part catered for by the EPIRB provision which is designed to activate automatically when floated free. Interestingly, Mr Arnold's point could have been more forcibly made in the days prior to 1st August, 1993, (at which date the EPIRB provision became mandatory) in respect of a cargo ship with a radiotelegraphy station, when almost invariably there was only ever one radio officer on board whose skills, due to the operational and technical complexities of the system, could not be replicated by anyone else on board.

It is clear from the nature of the points raised by Mr Arnold that they emerged from nothing less than a detailed reading of the LRTA Paper. That is always gratifying for any author, and hence his contribution is greatly appreciated.

Aspects of Maritime Satellite Communications and Radio Surveys



by R. A. Cooper

Roger Cooper had a long career with BT. Early in 1981 he joined the team which set up the maritime satellite service in the UK operating from BT's Goonhilly satellite earth station in Cornwall. On completion of this task in late 1982 when the team was wound up, he was assigned to the operational group responsible for running the service.

This was followed in mid 1983 by a two year spell as Head of Marketing and Forecasting for BT's maritime radio service. His last six years with BT was spent as Manager of Maritime Satellite Operations.

On 7th May 1991 Roger Cooper joined LR as a Specialist in Fleet Services Department responsible for statutory radio matters.

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Synopsis

The enormous technological advances in telecommunications during this century had been little remarked upon in Lloyd's Register Technical Association (LRTA) papers prior to the Author's contribution in November 1993 [Ref 1]. A notable exception was Professor E. W. Marchant whose Paper in 1921 [Ref 2] traced the work done by Hertz on electro magnetic waves, Marconi in detecting those waves over distance, Fleming's development of the thermionic valve and de Forest's introduction of grids in such valves as a means to amplify radio signals. Professor Marchant's Paper also made reference to Radio Direction Finding (RDF) as "One of the latest developments .....which has now been brought to a very great perfection". He went on to relate how during "The War" (1914-18), RDF technology enabled the British "..... to observe movements of the German fleet with considerable facility". The possibility of similar technology being used by the Germans to track the British fleet went unmentioned!

The RDF is still with us, notwithstanding the near pin point accuracy which may be afforded by Global Positioning Satellite (GPS) systems. The thermionic valves (or tubes) have, for the most part, been substituted by the transistor, and the technology expounded in the Author's previous LRTA Paper [Ref 1] has arguably been overtaken even before the full implementation of the Global Maritime Distress and Safety System (GMDSS), which that paper introduced; such is the pace of change in maritime telecommunications technology. The predominant physical feature reflected by the advance in technology over the years is the size of the equipment. This may be illustrated by the picture of a radio transmitter in Professor Marchant's 1921 Paper at Figure 1 (the range of which would likely not exceed 100 miles given good radio propagation conditions and considerably less than that in less than good conditions) compared with the satellite transceiver projected to be available around 2000 AD at Figure 2 whose range will be global and less affected by variable radio propagation conditions.

Interest in the Author's previous Paper [Ref 1] was not confined to LR. The reasons for this is that it presented an independent source information document on a topic affecting all Convention ships, at an opportune time, and in a concise fashion not readily available elsewhere. Other material available on GMDSS Radio tends either to be framed in verbose "regulatory language" or written by radio equipment suppliers to their own agenda. For all these reasons, LRTA No.2 of the 1993/94 Session has become a standard text on GMDSS Radio not only within LR, but also for those radio companies whose surveyors carry out work for classification societies, maritime training establishments, telecommunications authorities and a number of government agencies around the world concerned with regulatory issues and maritime safety. The number of copies distributed from the three print runs (there will be no more) was the largest in the history of the LRTA. In this respect the scale of interest from all quarters could be a reflection that radio is a subject which seldom features as an LRTA topic. Two such papers in the long history of the LRTA - in 1921 and again in 1993 - followed

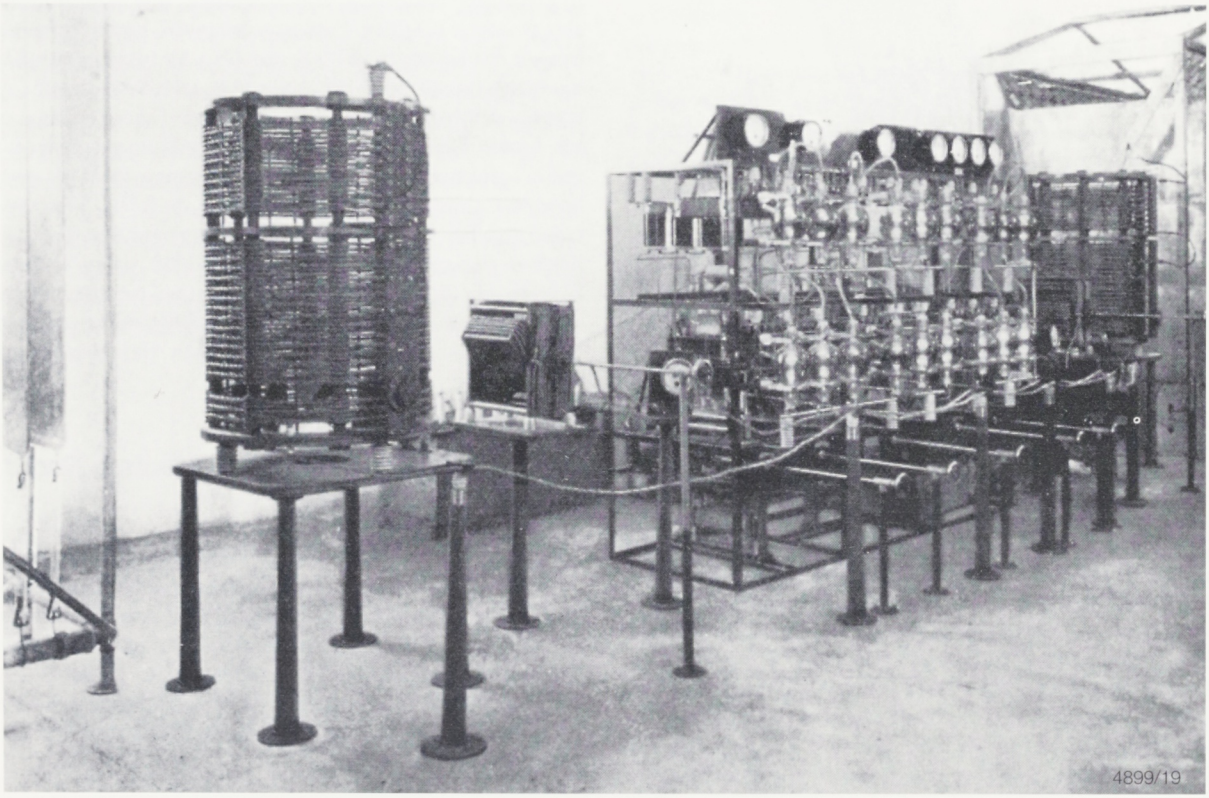


Figure 1
Radio Transmitter of the 1920s

by a third now, is hardly saturation coverage of a subject in which the pace of technological change is so rapid.

This current Paper addresses the need of a readership requiring information on modern maritime radio communications technology, both general and specific. The general areas include sections on the INMARSAT Organisation and System, its contribution to Maritime Distress and Safety Services (DSS) and the impact on the shipping industry from recent developments in telecommunications technology. The specifics include sections on the installation of satellite Ship Earth Stations (SES) on board, commissioning procedures for those SESs, and radio surveys. There is also a section on the consequences of the advances in maritime communications technology, including the problem of false alerts and how this may be addressed by ship masters, and the take up of the GMDSS by ship owners. Finally, the developments we can expect in the early part of the 21st century are considered.

The aim of this Paper is to equip LR people with a greater insight of maritime radio matters where gaps in knowledge may previously have existed. In so doing, LR clients' needs will be better served.

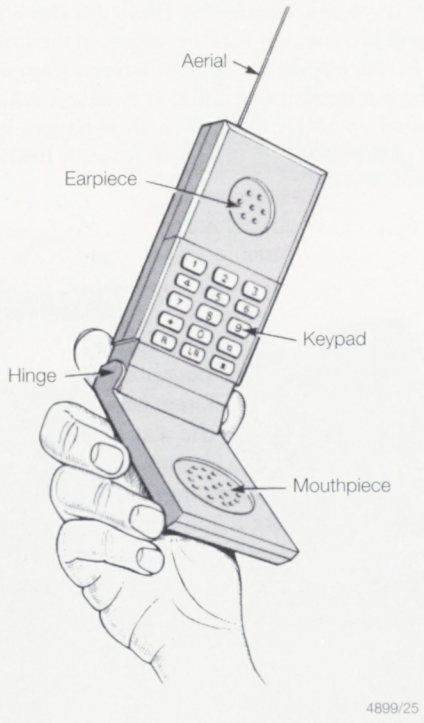


Figure 2
Hand Held Satellite Transceiver projected to be available around 2000AD

1 Introduction

1.1 One Man's Theory

The use of satellites in space for communicating radio signals is a relatively old concept when set against the time span over which radio technology has evolved. Less than 50 years after the first ever radio message transmission across water, the idea of using a satellite to relay signals around the earth was published in a popular technical journal [Ref 3].

The author of that article, Arthur C. Clarke, described how a satellite some 36,000 km above the equator would travel in space at the same rotational speed as the earth and hence remain in the same position relative to it. This has come to be known as a "geostationary orbit". Arthur C. Clarke further accurately calculated the energy required to put a satellite into this geostationary orbit and, having done so, use it as a radio relay station.

1.2 Early Experiments

It was left to the applied technologists to develop means of proving, or otherwise, the practicalities of Clarke's theories. The first challenge was to overcome the earth's gravitational force needed to place a man made satellite into orbit. The scientists of the then USSR achieved this with the launch of Sputnik in 1957. The next challenge was to determine the practicality of relaying line of sight radio signals via a satellite. This was achieved by experiments carried out jointly in the UK and USA by utilising a ready made satellite of the earth - the moon. In 1959 radio signals transmitted from Jodrell Bank in England were beamed at the moon. The reflected radio signals bounced from the moon's surface were received approaching three seconds later in Cambridge, Massachusetts in the USA. This time lapse matched the speed of radio energy over that distance. Further experiments took place in 1960 using a large balloon positioned in the outer regions of the earth's atmosphere over the mid west USA. This device, named Echo 1, reflected radio signals between New Jersey and California.

1.3 Man Made Space Satellite as a Radio Relay Station

The scene was thus set for the development of space satellites as radio communications relay stations. Such relay stations, where beamed radio signals are received and re-transmitted in real time (immediately) on a different frequency, was already well established technology. The challenge was achieving it via a relay station in outer space. Telstar, launched in 1962, was the first communications satellite to achieve this.

Telstar followed an elliptical orbit ranging from 950 km to 5600 km above the earth. This enabled the ground stations,

which had been set up in the UK and USA, to communicate with voice clarity of a quality far in excess of anything previously experienced in the radio spectrum over such a distance, albeit for only about half an hour a day when both stations had simultaneous line of sight vision of the satellite.

1.4 Commercial Realisation

It was Telstar which, more than anything, presented the realisation of Arthur C. Clarke's prediction of the commercial potential of space satellites in telecommunications technology. Whilst Telstar was funded entirely from the private sector (predominantly in the USA) the conventional wisdom of the time was that the potential for satellite communications could not be fully realised without national governments' support; financially and politically.

The financial and political linkage was important because the awesome costs involved in developing satellite telecommunications technology are such that ultimately, no one country would be able to provide the entire funding. Hence, the joint ownership of satellites through consortia such as INTELSAT, EUTELSAT, INMARSAT, and others. In the 1960s, government funded agencies, principally the National Aeronautical and Space Administration (NASA) in the USA, the European Space Research Organisation (later regrouped ESA - the European Space Agency) and the National Space Development Agency (NASDA) of Japan, were the sources of funding.

With the cold war still in place, it was inevitable that some of the development work on satellite communications would be directed at the military potential. In this respect, the US military had sought to enhance their navy communications world wide, and in particular in South East Asia. Whether due to an over estimation of requirements or, perhaps, a realignment of military global commitments away from South East Asia, spare US military satellite communications capacity became available in the mid 1970s. This enabled the Communications Satellite Corporation (COMSAT) in the USA to lease the necessary satellite capacity to establish their "Marisat" service in 1976 - the first ever maritime satellite communications facility to serve the merchant shipping market and the predecessor to INMARSAT.

2 The Inmarsat Organisation and System

2.1 The coming of INMARSAT

Prior to the establishment of the Marisat service, the International Maritime Consultative Organisation (IMCO) had acknowledged the potential for maritime satellite communications in the shipping industry. The conventional thinking of the day among the constitutes of IMCO was that such a service should come under a single international organisational umbrella; otherwise, it was thought, competing systems would inevitably emerge which, due to the high financial capital requirements, would result in global groupings, or blocs, each offering their own maritime mobile satellite communications facility. Such groupings, it was thought, would unlikely be able to provide the appropriate synergy, in terms of financial resource and allocation of scarce satellite capacity, as would a single world organisation.

The IMCO view prevailed. INMARSAT was established in 1979 with sole global monopoly responsibility to procure, administer and operate space satellites and their control systems to facilitate a global maritime satellite telecommunications service to be available to world shipping of all flags. It was agreed that INMARSAT should be governed and funded through "signatory" organisations and that each participating government would nominate just one such signatory. Signatories are commonly, but not exclusively, the dominant provider of satellite telecommunications services in the member country. In the USA, the signatory to INMARSAT is Comsat General and it is British Telecom (BT) in the UK. Funding is apportioned between each signatory organisation on the basis of the usage made of the INMARSAT system by the signatory country and its flag ships.

The scene was thus set for INMARSAT to become operational on 1st February 1982 with the inaugural call (Figure 3) made by the widow of Marconi to the Master of the QE2. On that day Comsat General and Kokusai Denshiu Denwa (KDD) of Japan, who by then had entered a collaborative arrangement with Comsat General, relinquished to INMARSAT the role of sole provider of maritime satellite services.

2.2 INMARSAT Operational Structure

Since its inauguration, INMARSAT has grown both in size and influence. Its activities have expanded into land based and land mobile operations as well as aeronautical. Further diversification is planned for global hand held satellite phones similar in appearance and size to cellular mobile phones (Figure 2). For the purpose of this paper, consideration will be directed to the maritime service which still remains the dominant business activity of INMARSAT, and this will be reflected by the terminology used in this Paper.



Figure 3

The INMARSAT communications structure comprise three components:

- the space segment;
- the ground segment; and
- the Ship Earth Stations (SES).

2.3 The Space Segment

The space segment is provided solely by INMARSAT and consists of four satellites plus back ups and reserves ready to be brought into service should the need arise, either for operational reasons or in the event of failure. At the time of writing, INMARSAT is progressively bringing into service their third generation satellites. The structures which form these satellites are built by Astro Space, a part of the Lockhead Martin Corporation. The communications element, which includes the antennas and repeater stations, are provided by Matro Marconi Space. As the working environment of a satellite is the void of space, there is no operational constraint with regard to shape; for example, to facilitate streamlining or other features to combat the vagaries of an atmosphere laden environment. Hence, what a space satellite may lack in aesthetic design with various bits attached to a box structure, is more than compensated by the convenience of being able to install sophisticated electronic and mechanical components without "packaging" design constraints. The cutaway drawing at Figure 4 shows the various components of a third generation INMARSAT satellite [Ref 4]. The structure includes two dish shaped antennas and six panels of solar cells comprising 328 square feet ($30.5m^2$) of surface area faced toward the sun. This produces at least 2,800 watts of power throughout the minimum thirteen years of the satellite's life. It is important for the satellite to remain precisely orientated in space and to achieve this there are sixteen thrusters. The amount these are used is the main factor which will determine the satellite's operational lifespan - the less the thrusters are used the greater will be the margin that the satellite will exceed its minimum operational life.

Each satellite's coverage area on earth is known as a footprint, defined as the area on the earth's surface within which an SES or Coast Earth Station (CES) antenna can obtain line of sight communications with the satellite. Each footprint is named in accordance with the ocean region that the satellite predominantly serves as follows:-

- Atlantic Ocean Region East (AOR-E)
- Atlantic Ocean Region West (AOR-W)
- Indian Ocean Region (IOR)
- Pacific Ocean Region (POR)

Each footprint overlaps with its neighbours to a greater or lesser extent. Figure 5 shows the configuration of the four satellites in space and their footprints corresponding to the four regions.

The operational integrity of the space segment is of a high order with in service time only fractionally less than 100% and generally in excess of 99.98%. It is on the basis of this high level of service reliability that the IMO agreed, in respect of the 1988 amendments to the 1974 SOLAS Convention relating to the duplication of certain equipment in a GMDSS Radio station, that an SES may be duplicated by a second SES despite their both using the same system. INMARSAT satellites are controlled from the Satellite Control Centre (SCC) at INMARSAT HQ in central London.

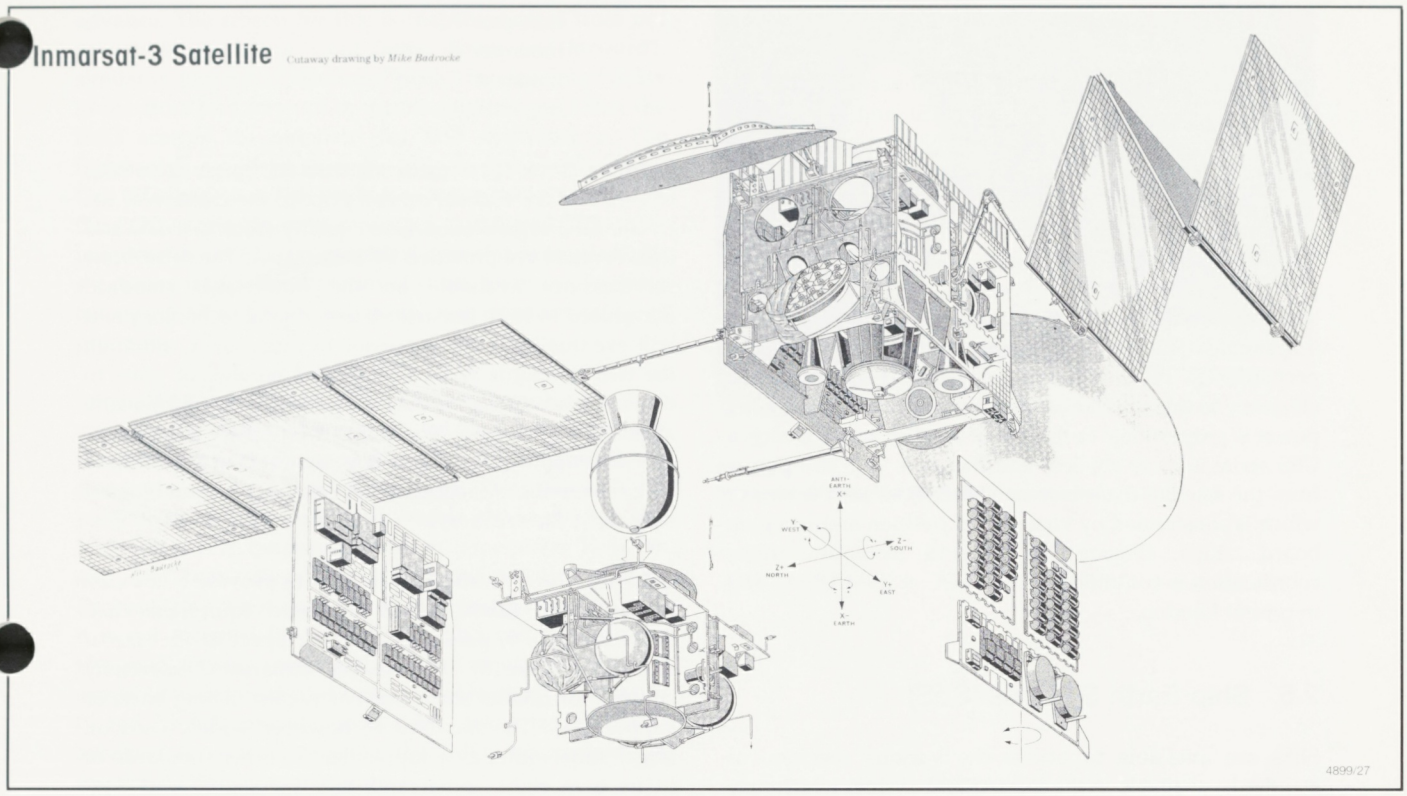


Figure 4
3rd generation INMARSAT satellite. These are in the process of being deployed at the time of writing this Paper

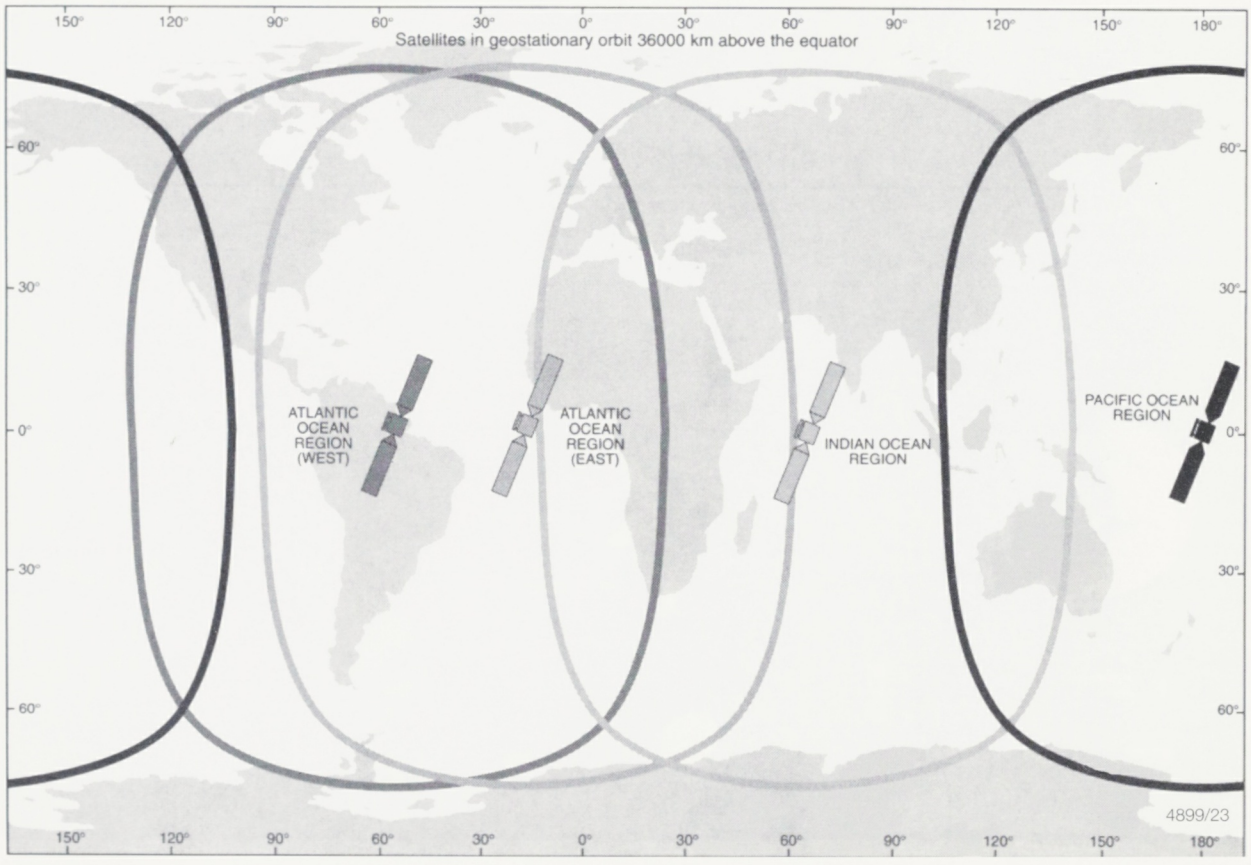


Figure 5
Satellite "footprints" in the INMARSAT system

2.4 The Ground Segment

The ground segment comprises a global network of CESs, Network Coordination Stations (NCS) and a Network Operations Centre (NOC). CESs and NCSs are owned and operated by telecommunications administrations. There is one NCS per standard (see section 2.5) serving each footprint to coordinate traffic among all the CESs offering service within the footprint region. CESs provide the access point, or "gateway", between the satellites and the telecommunications infrastructure of the country in which it is situated. CESs each utilise a large dish aerial which is permanently beamed at the satellite (Figure 6). The efficiency in transmission and reception of a given radiated power is proportional to the size of the dish aerial. Hence, a CES aerial is more efficient and therefore uses less power from the satellite than does an SES dish aerial, the size of which is constrained by virtue of its position and siting on board ships (Figure 7). Overall communications coordination is controlled by the NOC at INMARSAT HQ in central London.

2.5 Ship Earth Stations (SES)

SESs are available to utilise the various services, or standards, available in the INMARSAT system which may be offered by CES operators. The current standards are designated:

Inmarsat -A;
Inmarsat -B;
Inmarsat -C; and
Inmarsat -M.

Inmarsat-A was the original standard and hence dates back to 1976 and the Marisat service prior to the creation of the INMARSAT organisation. Good quality voice, fax, data and telex services are provided by Inmarsat-A. The same basic services are available on the Inmarsat-B standard introduced in 1994. Inmarsat-B uses digital technology and will eventually be the successor to Inmarsat-A, although the two standards will co-exist for a number of years to come. Higher speeds of data transmission are additionally available on Inmarsat-B, making it especially suitable for specialist applications where large amounts of data need to be transferred on a regular basis, such as on seismological surveys of the ocean bed.

Inmarsat-C was introduced in 1991 to provide a low cost facility using smaller sized on board equipment than Inmarsat-A or B, particularly with respect to the size of antenna (Figure 8). This makes Inmarsat-C especially suitable for smaller ships, such as yachts, fishing boats or supply craft. The standard is, however, widely used on larger ships either as a supplement to other standards or in its own right. Inmarsat-C is a messaging and data transmission system – it does not provide voice communications. The transmission is prepared in

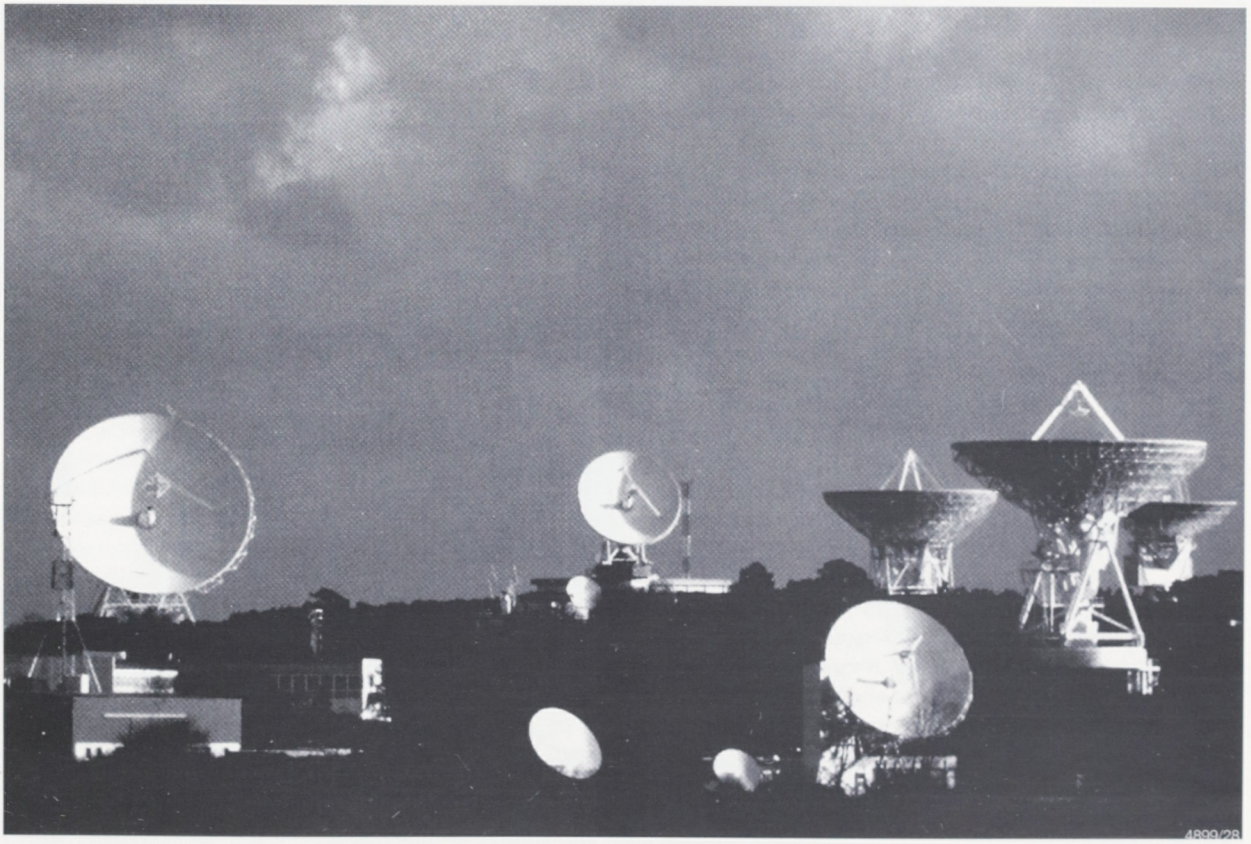


Figure 6
Satellite Dish Aerial Farm

advance. The reason for this is that the system does not operate in "real time", but rather "store and forward"; similar in practice to electronic mail. The element of delay in the store and forward system is minimal such that the IMO accepts the standard for DSS applications. The Inmarsat-C standard incorporates an Enhanced Group Call (EGC) service. This enables shore based subscribers to the EGC service to send messages to selected SESs on a broadcast basis to a geographical area (for example, IMO sea areas) or to defined groups of ships, for example, those belonging to a specific company, flag or other category grouping.

Inmarsat-M was introduced in 1992 to provide a low cost voice service using more compact on board equipment than that available with Inmarsat-A and B. Like Inmarsat-B, the standard uses digital technology and, like Inmarsat-C, is particularly suitable for smaller vessels, although again like Inmarsat-C it is commonly used on large ships. Both fax and data transmission may be passed via Inmarsat-M. Because telex is not available on the Inmarsat-M standard, it is not accepted by the IMO for DSS communications. However, for ship owners who do not require the facilities available with Inmarsat-A or B, a combination of Inmarsat-C and M will provide good voice, telex, fax and data services, as well as meeting the IMO requirements in respect of DSS communications.

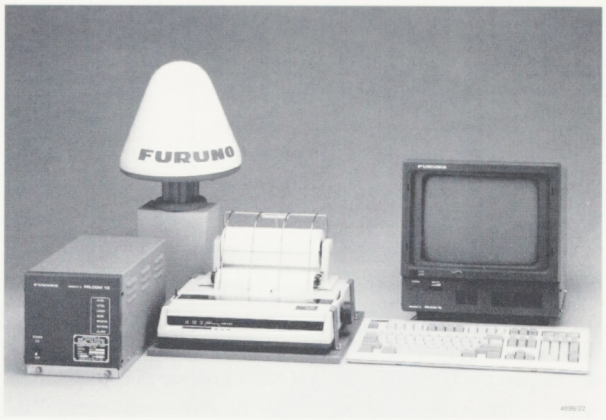


Figure 8
Inmarsat-C Ship Earth Station equipment

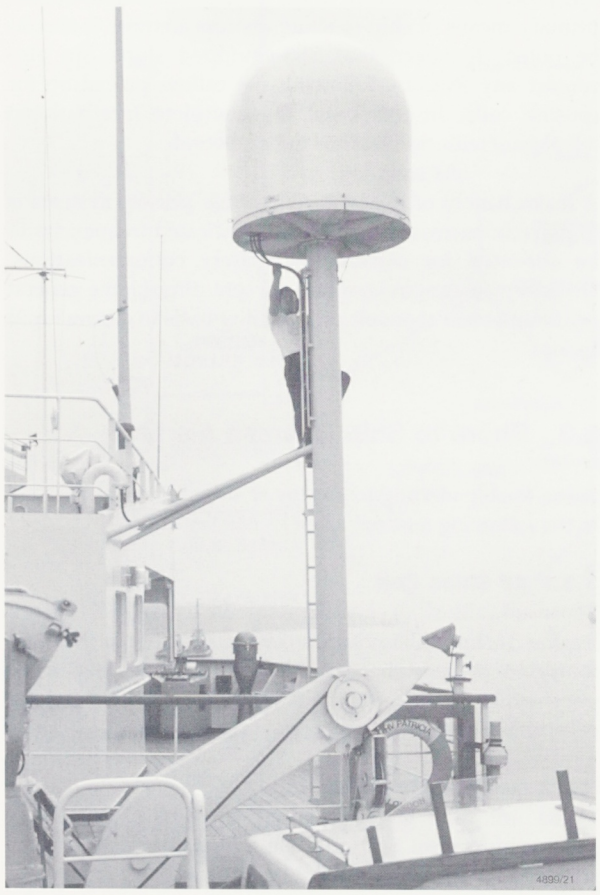


Figure 7
Ship Earth Station radome which encloses a directional dish aerial as used with Inmarsat-A and B systems

3 Distress and Safety Services

3.1 Background

After many years of international consultation with its constituent administration organisations representing the maritime interests of national governments, the IMO developed the GMDSS [Ref 1]. This was done in coordination and with the cooperation of the International Telecommunications Union (ITU), World Meteorological Organisation (WMO), International Hydrographic Organisation (IHO), maritime radio equipment manufacturers and suppliers, ship owners' representatives – such as the General Council of British Shipping (GCBS) and International Chamber of Shipping (ICS) – shipping industries' employee representatives, telecommunications' authorities as well as INMARSAT itself. In essence, the IMO acknowledged that the existing DSS reflected the technology available in the first half of the 20th century with its reliance on morse telegraphy and rescue coordination by ships in the vicinity, assuming there were any around. Hence, the GMDSS encompassed the available technology of the day – essentially the capability to have global telecommunications without an attendant high level manipulative skill to operate and maintain equipment. The GMDSS was thus incorporated into the SOLAS Convention through the 1988 Amendments. The DSS under the GMDSS exploits the full ambit of telecommunications technology, not just satellite communications.

3.2 Ship to Shore Distress Alerting

The DSS under the GMDSS provides priority alerting for use in distress emergency situations. Distress priority alerting in the INMARSAT system applies not only with respect to satellite channels, but also to the automatic routing of the distress alert call to the appropriate Rescue Coordination Centre (RCC). Each CES in the system provides reliable communications with an RCC. The means of CES - RCC interconnection varies from country to country, and may include the use of dedicated lines or public switched networks. A distress alerting message received at a CES is automatically processed and passed to its associated RCC where, depending on the national administration arrangements, the message may be:

- passed to special operators who are responsible for the subsequent routing of the call to the appropriate RCC; or
- in the Inmarsat-A and B systems, the CES may provide an option allowing the on board operator to contact any RCC by the assignment of a satellite channel.

3.2.1 Inmarsat-A and B Distress Alerting

Every Inmarsat-A and B SES is capable of initiating a "request" message with a distress priority indication which is automatically recognised at the CES where a satellite channel is instantly assigned. If all satellite channels happen to be busy, one of them will be pre-empted and allocated to the SES which initiated the distress priority call. The processing of such calls is completely automatic. The CES personnel are notified by audio-visual alarms of the reception and passing through of a distress priority message.

To ensure the correct treatment of distress requests, the NCS for the region automatically monitors the processing of distress alert calls by all CESs in that satellite footprint. In the event that any anomalies in processing are detected, the NCS takes appropriate action to establish the end-to-end connection. In addition, the monitoring NCS checks the CES identity contained in the distress priority message and automatically intercepts the call if an identity of a non-operational CES has been detected, which may happen due to operator error on board the vessel in distress.

3.2.2 Inmarsat-C Distress Alerting

Inmarsat-C SESs make use of a "Signalling Channel" for distress alerting. Using a special distress button, a short pre-formatted alert is transmitted directly to a CES. Distress priority ensures special processing at the CES for expeditious transmission to the associated RCC.

Information in the distress alerting format in an Inmarsat-C SES may be updated manually from the terminal keyboard. Automatic position updating, however, may be provided by any integrated electronic navigation receiver or by direct input from the ship's electronic navigation system.

3.2.3 Distress Communications

The procedures described in the above two sections are the primary means of ship-to-shore distress alerting. It should be noted, however, that SES-equipped ships can also contact any RCC by following the calling procedure for routine calls. In this case, the complete international telephone/telex number has to be selected.

A major benefit of INMARSAT distress priority systems is to make unnecessary the need for dedicated frequencies to be allocated for distress and safety communications. Distress messages transmitted are sent through the general communication channels on a priority basis to ensure rapid receipt.

3.3 Shore to Ship Distress Alerting

Shore-to-ship alerting to groups of ships can be performed in the following modes:

3.3.1 All Ships Call

These are calls to all ships in a specific INMARSAT Ocean Region. It should be noted, however, that due to the large footprints of geostationary satellites, such alerting is not very efficient, although it may be justified under exceptional circumstances.

3.3.2 Geographical area calls

These are calls to ships navigating in a defined of geographical area. Each satellite footprint is divided into small areas with boundaries based on IMO Navigation, meteorological or SAR areas (Figure 9).

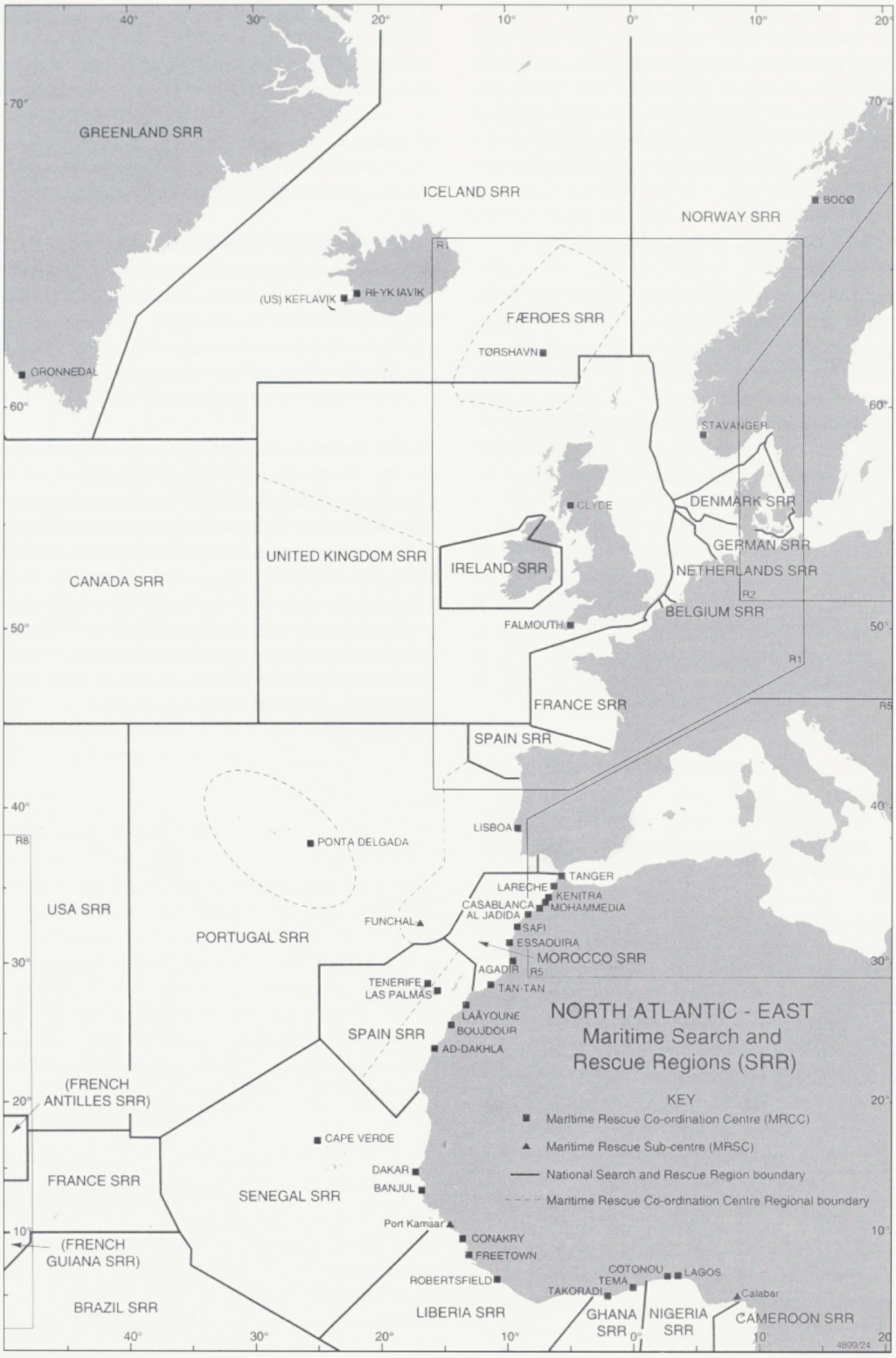


Figure 9
Allocated Search and Rescue regions

3.3.3 Group calls to selected ships

This service is provided by a number of CESs in the operator-assisted mode and allows alerting of a predetermined group of vessels, for example, to specific categories of ships whose assistance is particularly required.

3.3.4 Distress alerting through the SafetyNET service

An EGC receiver can be an integral part of an SES, or a completely separate unit. When a distress priority message is received, an audible alarm sounds.

Accessing the SafetyNET service by RCCs requires arrangements similar to those needed for shore to ship distress alerting to an SES. Those RCCs unable to obtain a reliable terrestrial connection to a CES can install an INMARSAT SES at the RCC. The RCC would then transmit the distress alert relay via the SES to a CES where it would be relayed by means of a broadcast through the SafetyNET service.

3.3.5 Search and Rescue (SAR) co-ordinating communications

For the co-ordination and control of SAR operations, RCCs require communication with the ship in distress, as well as with units participating in the operation. The methods and modes of communication used will be governed by the capabilities available on board the ship in distress, as well as those on board any assisting ships. Where those ships are equipped with SESs, the advantages of the INMARSAT system for rapid, reliable communications, including the receipt of Maritime Safety Information (MSI), can be exploited. These may be directed to specific regions – Figure 9. A reliable interlink of RCCs is important for the GMDSS where a distress message may be received by an RCC thousands of miles away from where the assistance is needed, although it may not be the RCC best suited to provide the necessary assistance. In such cases, prompt relay of the distress message to an appropriate RCC is essential.

To increase the speed and reliability of inter RCC communications, some RCCs have installed land based SESs providing them with the capability of communicating direct via the INMARSAT system. These facilities are useful for long distance interconnection of SAR organisations, especially when dedicated lines or public switched networks are unavailable or unreliable, as well as for communications with ships.

3.3.6 On scene SAR communications

On scene communications are those between SAR vessels and the OSC (On scene Commander) or the CSS (Co-ordinator Surface Search) and are normally short-range communications made on the VHF or MF DSS frequencies in the GMDSS. SES fitted ships can, if necessary, use satellite communications to supplement their VHF and MF facilities.

3.3.7 Promulgation of Maritime Safety Information (MSI)

In the INMARSAT system, promulgation of MSI for the International SafetyNET Service is performed by means of the Inmarsat-C Enhanced Group Call (EGC) capability. If uninterrupted receipt of MSI is required, or the Inmarsat-C SES is utilised for above average amounts of communications, then it is essential for the ship to have a dedicated EGC reception capability for MSI broadcasts. An EGC receiver is usually an integral part of an Inmarsat-C SES, but may also be installed as a separate unit. Figure 10 illustrates communication in the DSS.

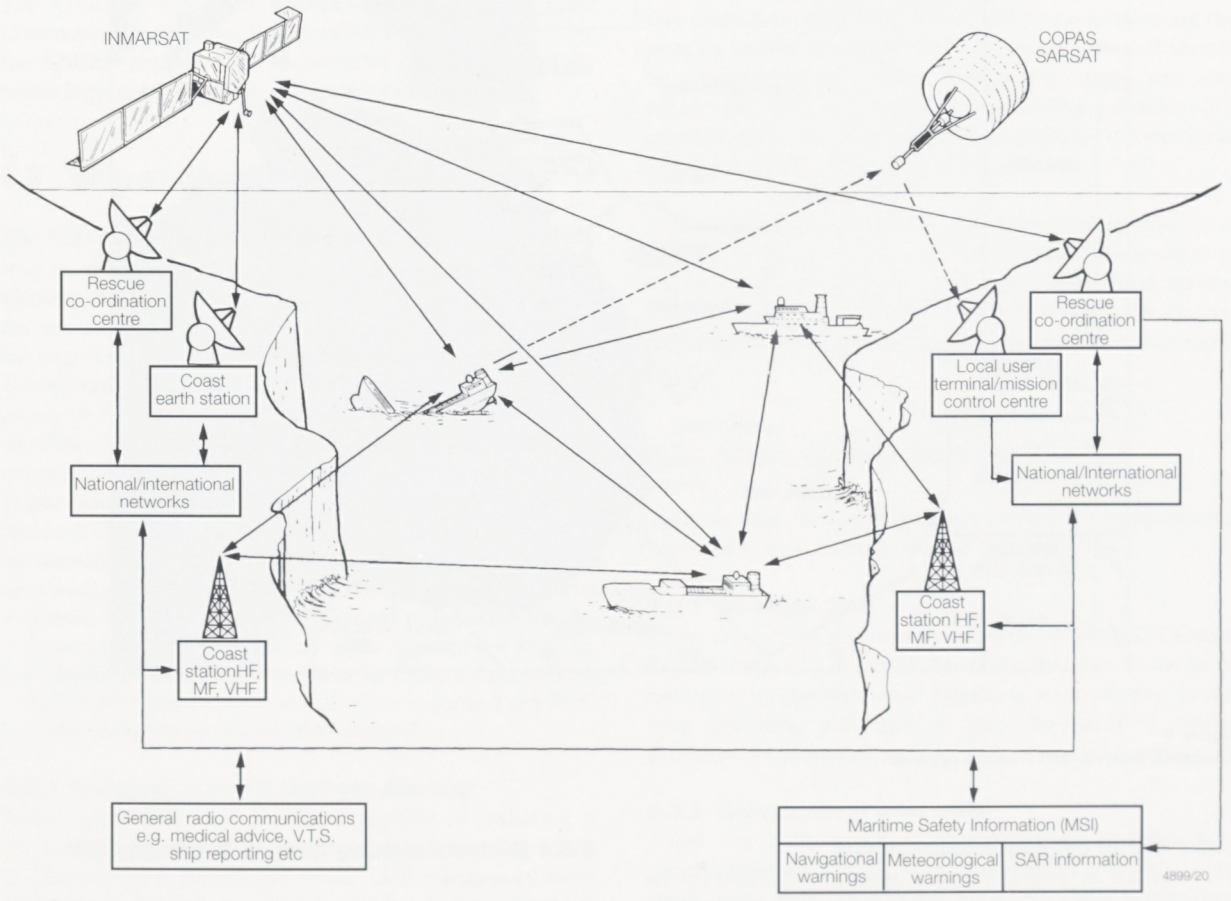


Figure 10
Communication links in the Distress and Safety Services

4 Guidance on fitting a Ship Earth Station onboard

4.1 Performance Specification

SES specifications are defined by INMARSAT [Ref 5, 6 and 7] to ensure that the equipment performs adequately and does not jeopardise the integrity of the INMARSAT system. In addition, performance standards [Ref 8, 9 and 10] for SESs are defined by the IMO to meet the requirements of the SOLAS Convention in respect of the GMDSS.

4.2 Technical Requirements

The SES must be type approved by INMARSAT and comply with the environmental requirements as specified for the particular standards of equipment, that is Inmarsat-A, B, C or M. Only those standards accepted by the IMO for the GMDSS are considered in this Paper and hence Inmarsat-M is not covered. Any additional facility which may be provided by the manufacturer beyond that specified by the IMO performance standard should not be allowed to inhibit, through either normal operation of the additional facility or consequent from a malfunction of it, the operation as specified by the IMO performance standard.

4.3 Equipment Controls

The controls of an SES are required to be simple, quick and effective. They must be arranged in a manner which minimises the chance of inadvertent operation. Those controls not required for normal operation should not be readily accessible. The design of the equipment must be such that misuse of the controls will not result in damage to the equipment or injury to a person. An alteration to an SES identity code should not be possible through operation of external controls. Keyboard layouts have to conform with the appropriate standards [Ref 11].

4.4. Equipment Operation

The means of initiating a distress call is required to be protected from inadvertent operation whilst not detracting from ease of operation. Distress calls are required to be capable of initiation from where the ship is normally navigated as well as from at least one other designated position. Adequate illumination must be provided to identify the controls and enable indicators to be read. Where appropriate, dimming of light sources must be available where interference with navigation could occur.

4.5 Power Supply

An SES is required to be powered from the ship's main electrical source and be capable of operation from an alternative source. This also applies to any antenna tracking system. Whilst arrangements for changing from one power source to the other need not be incorporated in the SES, arrangements for rapidly doing so should be available somewhere in the equipment. These arrangements should be such that there will be no interruption in operation or any requirement to re-initialise the equipment. This must similarly apply to an interruption from any cause of up to one minute, as well as a toleration of power supply variations normally expected on a ship. Protection from the effects of current and voltage overload and polarity reversal are also required.

4.6 Electro Magnetic Compatibility

All reasonable and practicable measures should be taken to achieve Electro Magnetic Compatibility (EMC) between the SES and peripheral equipment and other radio communications and navigation equipment [Ref 12]. Each unit of equipment should in installed such that:

- mechanical noise does not prejudice the audibility of sounds upon which the safety of the ship may depend;
- the minimum safe distance from compasses is clearly marked on equipment which may be located in the vicinity of compasses; and
- the performance of individual equipment must not be prejudiced when peripheral devices are connected.

4.7 Safety Precautions

All steps should be taken to ensure that radiated energy from SES equipment is not hazardous and all practicable measures taken to prevent accidental access to dangerous voltages. In particular, voltages exceeding 55 volts (other than RF voltages) are required to be protected. Such protection should include automatic isolation when protective causes are removed. Alternatively, the SES may be so constructed that access can only be gained by use of a tool, in which case prominent warning labels are to be displayed in the equipment and on the protective covers. Earthing should be provided, where it is appropriate. Radome coverings should be labelled to indicate the distances at which radiation of 100 W/m^2, $25W/m^2$, and $10W/m^2$ are present. Equipment likely to emit x-rays should:

- not exceed that which may be defined by the Administration where radiation is external;
- in the case of radiation within the equipment which exceeds that defined by the Administration, have a warning to that effect displayed inside the equipment; and
- where the possibility of a malfunction may result in an increase in x-rays, have a warning to this effect given in the equipment manual with the circumstances which may cause the x-rays to increase, and the precautions which should be taken.

4.8 Antenna Location

Inmarsat-A and B SES antennas should ideally be positioned such that there are no obstacles above a point 5^0

below the horizontal plane or within the main beam shaped as a 12º angle cone from the antenna. This is illustrated in Figure 11.

For Inmarsat-C, the antenna should ideally have no obstacles above a point 15º below the horizontal as shown in Figure 12. In practice, the presence of some metallic objects in the path of propagation between the antenna and the satellite may be difficult to avoid in all azimuth directions. Ideally, all obstructions within 3 metres of the antenna are best avoided as well as those exceeding 15cm diameter which are beyond 3 metres from the antenna. Where obstructions are unavoidable, their direction should be noted so that degradation in radiation performance related to the ship's heading may be predicted.

Warning indicators should be installed against entering a hazardous area surrounding an SES radome. Measured data will likely be available in the supplier's literature. In the absence of such information radiation levels may be assessed from Figure 13 for Inmarsat-A and B, and Figure 14 for Inmarsat-C.

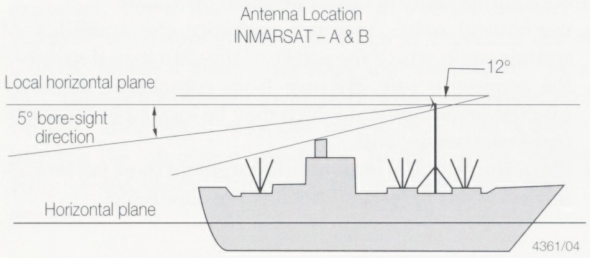


Figure 11

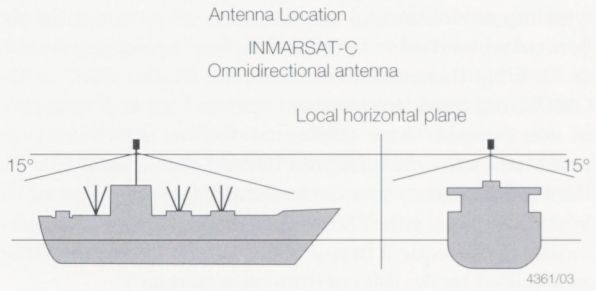


Figure 12

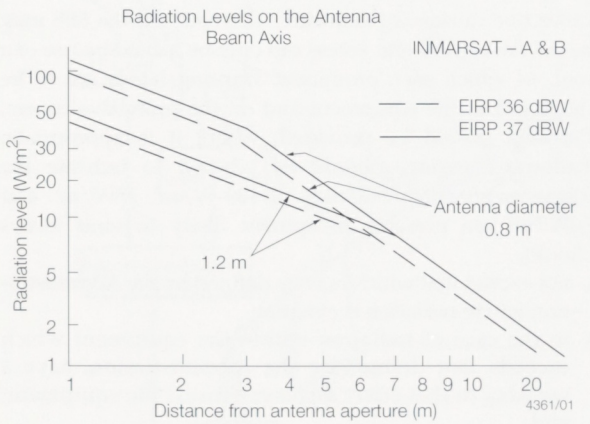


Figure 13

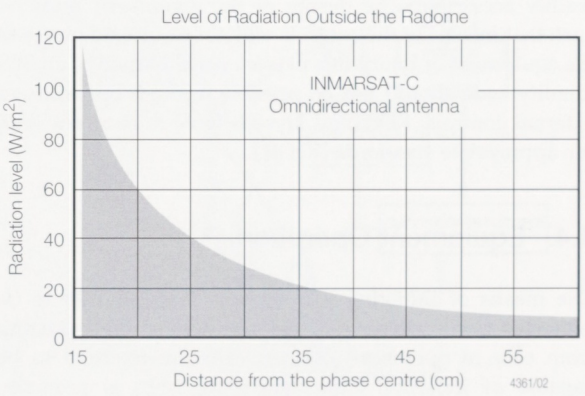


Figure 14

5 Ship Earth Station Commissioning Procedures

5.1 Governing Procedures and Purpose

Commissioning procedures for SESs are set out by INMARSAT [Ref 13] requiring every new SES to complete a standard process before being allowed to access the system. The purpose of commissioning is to ensure that the SES is registered in the INMARSAT system and tested to confirm it can communicate properly without causing interference to the system or to other users.

To register a new SES, a Commissioning Application Form is required to be submitted detailing the SES model, country of registration, installation type, owner, and accounting arrangements. Also, changes in circumstances relating to an already commissioned SES may require to perform a decommissioning and recommissioning process.

5.2 Elements in the Commissioning Process

Commissioning involves a sequence of tasks, some administrative and some technical, which must be performed at different times by various parties. The tasks involved are defined in the following groups:

- *Technical*
  - To perform functional tests on the SES to demonstrate that it is capable of providing reliable communications without causing interference.

- *Legal*
  - To ensure that the operation of each SES meets the legal requirements of the flag state and INMARSAT.

- *Financial*
  - To ensure that proper arrangements are made to pay charges for the use of the INMARSAT system.

- *Administrative*
  - To ensure that each SES is of a model that has been type approved by INMARSAT.
  - To ensure that the details from the SES Commissioning Application Form are entered into the INMARSAT Electronic Commissioning System (ECS).
  - Where a nationally type accepted INMARSAT SES is included as a component in a ship's radio installation designed to meet the IMO's GMDSS requirements, National Administrations may view successful commissioning of the SES as an essential pre-requisite to granting the installation a GMDSS certificate of worthiness.

More information on the GMDSS technical requirements for ship's radio installations may be obtained from:

Maritime Services Operation Dept
INMARSAT
99 City Road
London.
EC1Y 1AX
UK

Telephone: +44 171 728 1000
Fax: +44 171 728 1752
Telex: 297201 INMSAT G

5.3 Parties Involved in Commissioning

The different parties involved in commissioning and the tasks they perform are as follows:

5.3.1 The SES manufacturer

The equipment manufacturer assigns numbers to the SES as below:

- For an Inmarsat-C SES:
  The manufacturer programs into the SES memory a unique pair of numbers known as the FRLP (Forward/return linked pair). These are supplied by INMARSAT and comprise a "Forward ID" and "Return ID" to be used after the SES has been commissioned.
- For an Inmarsat-M or Inmarsat-B SES:
  The manufacturer assigns the following numbers to the SES:
  (i) An FRLP programmed into the SES memory.
  (ii) A unique ISN (Inmarsat Serial Number) assigned by the manufacturer to a single channel SES (or to each channel of a multi channel SES). The manufacturer should print the ISN on the SES casing or in the documentation supplied with the SES to enable the Commissioning Applicant to identify the channel for administrative purposes.
  (iii) A set of numbers known as the OID/DIDs (Originating Identifiers/Destination Identifiers) programmed into the SES to identify the end terminal ports available on the SES. (On a user programmable SES, the standard set of OID/DIDs assigned by the manufacturer may later be changed, for example by the Installation Engineer/SES User during installation, to suit the User's requirements).

The Inmarsat-A system does not use the above numbers, so the manufacturer does not need to program them in Inmarsat-A SES.

5.3.2 The Commissioning Applicant

The Commissioning Applicant is the person who completes a Commissioning Application Form supplying details of the SES model. The Applicant may be the SES owner/licensee/manager or its operator who should be familiar with the SES and its circumstances. When completing the form, the Applicant should nominate the name of a contact who can answer any questions that may arise. Typically, the Applicant for an Inmarsat-A SES may be a clerical officer in a shipping company, while an Applicant for an Inmarsat-C or Inmarsat-M SES may be the SES Owner/User. The Applicant must sign and date the completed form on behalf of the SES owner/licensee/manager to confirm agreement with the Terms and Conditions accompanying

the form. The Applicant should then forward the form by mail or fax to the National Routing Organisation (RO) for the country of registration of the vessel where the SES is to be installed. (See below for more information on the National RO).

5.3.3 The SES Owner/Licensee/Manager/User/ Operator

These different parties are defined as follows:-

- The SES owner may be a company or an individual. Typically the Owner is also the SES Licensee and/or User, as defined below.
- The SES Manager is the person appointed by the Owner to be responsible for the safe keeping of the SES.
- The SES Licensee is the company or individual who is registered with the National Licensing Authority as being responsible for the operation of the SES in communicating over the INMARSAT system.
- The SES User/Operator is the person who uses the SES to access the INMARSAT system and perform the required communication tasks.

5.3.4 The National Routing Organisation

In most countries, the RO is an organisation associated with the INMARSAT partnership. For example, an INMARSAT CES, the National Licensing Authority, or an Accounting Authority (AA). The following sections give more information on these organisations. The RO is generally located in the country of registration of the ship. To find the address of the National RO for a given country, contact the SES agent/manufacturer or the INMARSAT Commissioning Department at the address at the end of paragraph 5.2 above. It is important to note that commissioning Application Forms must be sent to the National RO for the country of registration of the ship and not to INMARSAT. The RO is responsible for the following activities:

- Acting as the interface between the Commissioning Applicant/SES User and INMARSAT in all matters relating to commissioning.
- Accepting and authorising the Commissioning Application Form from the Applicant and confirming that the details are correct, if necessary through the Contact Name on the form.
- For an Inmarsat-C or Inmarsat-M SES, assigning a unique IMN (Inmarsat Mobile Number) to all end terminals/services requested on the form. The IMN for an Inmarsat-A SES at present is assigned by the INMARSAT Commissioning Department, not by the RO.
- Arranging for the details on the form to be entered into the ECS by using a remote ECS software module or by mail or fax.

5.3.5 The Accounting Authority

An AA is an organisation nominated by an Applicant on the Commissioning Application Form for the purpose of administering the billing and settlement of the communication charges incurred by the SES after it has been successfully commissioned.

The function performed by the AA is to act as an intermediary between the SES owner/operating company and the CES(s) which supply communication services to the SES. If an SES incurs call charges with several CESs, each CES passes details of its charges to the AA. The AA consolidates all the charges from the CESs (and in most instances adds its own charge for administration) and submits a single bill to the SES owner/operating company for settlement. The SES owner/operating company must settle the bill with the AA. The AA settles the individual charges with the CESs.

To overcome problems of bills being issued or settled in many different currencies, an AA may bill an SES owner/operating company in nominal accounting currencies, such as the Special Drawing Right (SDR) or the Gold Franc (GF). Alternatively, by agreement, the AA may bill in an international currency, such as the US dollar.

An Applicant must choose an AA from the list published by the International Telecommunications Union (ITU). A copy of the list may be obtained from the National RO or from the ITU at the address:

Sales Service
International Telecommunications Union
Place des Nations
Ch-1211, Geneva 20
Switzerland

Telephone: +41 22 730 5111
Telex: 421000/421000 uit ch
Telegram: Burinterna GENÉVE

In the ITU list, each AA is assigned a unique identification code known as the Accounting Authority Identification Code (AAIC). The AAIC acting for every SES is stored in the Electronic Commissioning System (ECS). When an SES makes a call through a CES, the CES identifies the AAIC for that SES, and subsequently sends the charge for the call to the AA.

5.3.6 The Installation Engineer

The requirements for an Installation Engineer depends on the type of SES:

- An Inmarsat-A or B SES must be installed by an experienced Installation Engineer, generally nominated by the manufacturer.
- An Inmarsat-C SES generally does not require an experienced Installation Engineer, as the procedure is straightforward. This may, therefore, be performed by a non-specialist, for example the SES Owner/Operator. However, some manufacturers do require the SES to be installed by their nominated Installation Engineer under the terms of their Warranty Agreement. To find out about the installation conditions, contact the manufacturer/agent.
- An Inmarsat-M SES may need to be installed by an experienced Installation Engineer depending on the policy of the manufacturer – some manufacturers, under the terms of their Warranty Agreement, require the SES to be installed by their nominated Installation Engineer. Other manufacturers permit a non-specialist (for example the SES Owner/Operator) to install the SES. To find out about the installation conditions, contact the manufacturer/agent.

5.3.7 The Commissioning Agent

A Commissioning Agent acts on behalf of the SES Owner/Operator to ensure that the commissioning process is performed correctly. Generally, a Commissioning Agent is required when commissioning an Inmarsat-A SES which involves technical tests, but is optional for an Inmarsat-C or

Inmarsat-M SES which involve only simple tests. On the date appointed for the commissioning tests, the Commissioning Agent should be located at the SES and, for an Inmarsat-A SES, have available the test equipment required to perform the tests. No specialised equipment is required for the Inmarsat-C or Inmarsat-M tests. The Commissioning Agent then initiates the tests at the SES and follows the instructions of the Commissioning CES (see below for more information).

5.3.8 The Commissioning CES

For an Inmarsat-A, B or M SES, a Commissioning CES should be nominated by the Applicant on the Commissioning Application Form for the purpose of conducting tests on the SES to prove that it functions properly. An Inmarsat-C SES does not require a Commissioning CES to be nominated.

5.3.9 The INMARSAT Commissioning Department

The INMARSAT Commissioning Department in London is the core department in the commissioning process. It is responsible for ensuring that all tasks related to commissioning (and decommissioning) are performed properly by the parties involved. The Commissioning Department must also ensure that commissioning information is distributed throughout the system to the NCSs, CESs and AAs, using the ECS as described in paragraph 5.4. The INMARSAT Commissioning Department is willing to assist any parties experiencing difficulties with commissioning.

5.4 The Electronic Commissioning System

The ECS is a software system which holds details on all commissioned SESs. Different elements of the ECS are held on computers at various locations, as below, interconnected by public telecommunications networks:

- The Central ECS, held in the INMARSAT Headquarters in London.
- The Remote ECS, comprising the following elements:
  (i) The CES-ECS, held in each CES.
  (ii) The RO-ECS, held by a growing number of (but not yet all) ROs.

5.5 Type and Case Approval

The INMARSAT partnership does not manufacturer SES models, but lets manufacturers submit their designs for approval against technical standards defined by INMARSAT. Only those models which meet these standards are granted formal type approval. The information in this LRTA Paper is not specific to any particular type approved model but is intended to be generic in nature. For specific information on a particular model refer to the manufacturer's instructions.

Inmarsat-A, B, C and M commissioning procedures differ in some significant respects and reference should be made to the appropriate INMARSAT guidance [Ref 13] on the matter.

5.6 Validity of Commissioning

After an SES has been successfully commissioned it remains authorised to communicate through the system until any significant change occurs to the SES or its circumstances. The action required depends on the nature of the change, for example if the:

- change is only administrative, such as a change in owner, manager or licensee, without affecting the operation of the SES, the only action required may be to inform the National RO which will arrange to have the records on the SES updated in the ECS;
- change is likely to affect the operation of the SES, such as a change in SES model or installation, it may have to be decommissioned and recommissioned – paragraph 5.7 refers; or
- SES is being operated incorrectly, caused either by malfunctioning or by operator action, the SES may be barred from accessing the system. See paragraph 5.8 below.

In the event of any of the above changes, the National RO should be contacted to find out the required action.

5.7 Decommissioning and Recommissioning

In the event of a change which could affect the operation of an SES, such as a change in model or installation, the SES User should inform the National RO and await the following arrangements:

(i) The RO will inform the User of any change in IMN(s) assigned to the SES and confirm the date and Commissioning CES for any new tests required.

(ii) On the appointed date, the SES User should perform the tests, in conjunction with the Commissioning CES.

(iii) Also on the appointed date, INMARSAT will use the ECS to decommission the SES with its original circumstances and await confirmation from the CES of the results of the tests.

(iv) On successful completion of the tests the following will occur:

- The CES will inform INMARSAT HQ who will take the necessary action, depending on whether or not the SES is still to be used. If the SES is still to be used, then INMARSAT will recommission it by entering its new details into the SES. If, however, the SES is not to be used again, then INMARSAT will simply keep it decommissioned in the ECS until informed otherwise.
- The CES will confirm with the SES user that the SES is approved to communicate over the INMARSAT system.

5.8 Barring an SES

If an SES is being operated incorrectly, INMARSAT may bar it from accessing the system. The type of barring imposed may be either technical barring or discretionary, depending on the nature of the incorrect operation, as discussed below:

5.8.1 Technical barring

If an SES is malfunctioning and causing interference to the

system and/or to other users, perhaps without the SES User realising it, a CES may request INMARSAT to issue a technical barring to stop the SES communicating until it is repaired. The extent of this technical barring depends on the nature of the system interference:

- If the fault in the SES is causing interference to routine priority communication, the SES will be barred from sending or receiving routine priority (commercial) calls through all CESs, although the SES will still be able to make distress calls.
- If the nature of the fault causes the SES to produce random distress calls, then the SES will have to be barred from making any distress calls. The SES may also be barred from sending or receiving commercial calls through all CESs. In this event, the CES which detected the interference and/or INMARSAT will attempt to warn the SES User that the SES is being disabled from making distress calls.

5.8.2 Discretionary barring

If an SES is in serious breach of its contractual obligations with particular CES Operators, AAs or Billing Entities, for example for non-payment of bills, they may request INMARSAT to introduce a discretionary barring through specified CESs. This type of barring means that the SES will not be permitted to send or receive commercial calls through those particular CESs, but will still be able to make distress calls. In the event of a discretionary barring, INMARSAT will inform all other CESs who will decide whether they will also bar the SES from communicating through them.

6 Radio Surveys

6.1 Types of Surveys

It is a statutory requirement of the IMO that all Convention ships shall be subjected to an annual radio survey to ensure its radio equipment is in good operational order. These surveys are the responsibility of government administrations who may devolve the work to classification societies. Certification is always on behalf of a flag state government.

Convention ships in respect of radio are defined as cargo ships of 300 GRT or more and all passenger ships, defined as ships of any size, which carry twelve or more fare paying passengers. There are currently three types of ship radio stations for which surveys are carried out:

- GMDSS Radio, which may be applicable to all convention ships;
- radiotelephony, which may be applicable to cargo ships of less than 1600 GRT; and
- radiotelegraphy, which may be applicable to passenger ships irrespective of size, and cargo ships of 1600 GRT and over.

The GMDSS Radio station became an option on 1st February 1992 and will be obligatory for all Convention ships by 1st February 1999 at which date radiotelephony and radiotelegraphy ship stations should cease as available options. 1st February 1992 to 1999 is therefore a seven year transition period to enable shipowners to install GMDSS Radio stations. For more information on GMDSS Radio, reference should be made to the Author's previous LRTA paper [Ref 1].

6.2 Radio Survey Requirements

LR has traditionally utilised the services of radio companies with expertise in maritime radio to carry out its radio surveys. This arose from the specialist technical and operational skills needed to manage a ship radio station, particularly radiotelegraphy which formed the majority. With the transition to the GMDSS Radio station, which exploits more recent technology and use of automated systems capable of being operated by those whose primary skill responsibility is other than radiocommunications, there may be scope for LR surveyors to attain the requisite skills to conduct radio surveys. That aside, an LR surveyor in accepting a survey carried out by a specialist radio surveyor should be satisfied that the work has been competently done. This includes documentation (Record of Installation Forms 2116 or 2138, Checklist Forms 2115 or 2137, the Radio Certificate Form 1705 and its "Form R" attachment, Form 2131) properly and accurately completed. Appendices A to D show specimen examples of completed GMDSS Radio Installation Records and Checklists for the guidance of radio surveyors as well as LR surveyors in assessing the documentation presented by radio surveyors. In particular, the Record of Radio Installation Forms 2116 or

2138 should be typewritten. This is because, after checking at HQ, they are sent to the shipowner for placing on board and a typed document is presentationally appropriate for this purpose. Specimen examples of radio certification documents shown at appendices C to F of [Ref 1] remain applicable except in respect of Section 2.2 of the Form 'R' attachment to a GMDSS Radio installation certificate which should indicate the actual equipment which provides the secondary means of alerting [Ref 14]. Thus, rather than "Yes" in Section 2.2 of the example at Appendix C at page 38 of [Ref 1] the appropriate entry should be, for example, "Satellite EPIRB" or "INMARSAT SES" or "HF DSC" etc. More usually it will be "Satellite EPIRB".

6.3 Assessment and Acceptance of Radio Surveyors

It is the responsibility of the appropriate Regional or Country Manager to authorise sub-contractors to carry out Radio Surveys on behalf of LR. Assessment and acceptance of sub-contracted radio surveyors should be on the basis of the following guidelines.

6.3.1 Acceptance Criteria for Radio Surveyors

(a) Existing Radio Surveyors who have demonstrated their capability in providing a satisfactory service to LR over a minimum period of five years may be accepted on that basis; or

(b) Radio Surveyors who hold an appointment as a Radio Surveyor under the authority of the national administration may be accepted without assessment; or

(c) New Radio Surveyors should be assessed by LR staff using the guidance shown in paragraph 6.3.2.

6.3.2 Assessment of Radio Surveyors

(a) Radio Surveyors must have a comprehensive knowledge of the SOLAS Convention in respect of radiocommunications, its operational application on board, and the ITU Radio Regulations;

(b) Radio Surveyors should be aware of local conditions for radio signal propagation, regional radio stations and their facilities as well as the GMDSS infrastructure;

(c) In order to operate or test radio transmitters, Radio Surveyors must hold an appropriate national Radio Operator Certificate recognised by the ITU. If a Radio Surveyor is not certificated for the radio station being surveyed then he or she may only transmit under the direct supervision of a person who is qualified, for example, one of the ship's crew who has a valid radio operating certificate.

6.3.3 The Requirements of a Radio Surveyor

The Radio Surveyor is required to:

- survey ships' radio installations in accordance with the SOLAS Convention, specific flag requirements and ITU Radio Regulations (RR);
- complete LR's radio documentation;
- report survey results promptly indicating significant features, particularly any outstanding items which need to be attended to, whether the ship changed flag, details of equipment changes, etc.; and
- comply with LR Quality Assurance (QA) procedures.

6.3.4 Verification

Effective controls should be maintained over the work carried out by Radio Surveyors providing the services detailed in paragraph 6.3.3 by the Regional or Country Manager and by QA audits.

6.3.5 Records

A list of approved sub contracted Radio Surveyors and the surveys each one carries out should be maintained. These should be reviewed as considered necessary by the local offices, but not less than annually.

6.4 Ancilliary Radio Items

There are a few radio items which in the past were regarded as coming within the ambit of radio but are now, in fact, requirements of the Safety Equipment Certification process. These are some Life Saving Appliances (LSA), Radars, Automatic Radar Plotting Aids (ARPA) and RDF. Since the introduction of the GMDSS on 1st February 1992, Radars, ARPAs and RDFs (including calibration) have been controlled solely through the Safety Equipment Certification process. Radars, ARPAs and RDFs are not included in any radio documentation now issued from HQ so any radio documentation held which does refer to these items will be obsolescent stock.

LSA items are similarly controlled through the Safety Equipment Certification process, but the functioning of those defined as radio LSAs, namely Radar Transponders (SART) and two-way (hand held portable) VHF radiotelephones, are also required to be verified at the radio survey [Ref 15]. This is indicated as such on the radio certificate at paragraph 2.2 as shown in the appendices C to F pages 37, 40, 43 and 46 of [Ref 1]. The following relating to SARTs and two-way VHF radiotelephones explains regulatory aspects relevant to these equipments, which will help surveyors and others dealing with radio documentation to understand better the requirements.

6.4.1 Radar Transponders

The specific statutory requirements in respect of the number of SARTs on Convention ships are:

- two for Safety Equipment certification on all passenger ships and on cargo ships of 500 GRT and over [Ref 16];
- one for Radio certification when a GMDSS Radio station is on board [Ref 17] which may be one of those (or the one in the case of a cargo ship of less than 500 GRT) provided to comply with the Safety Equipment certification requirement; and
- none for Radio when a radiotelegraphy or radiotelephony station is on board [Ref 18].

The consequence of these requirements is reflected on the Form 'R' attachment to the Radio certificate where "1" is indicated at Section 2.6 in respect of a GMDSS Radio station (see also paragraph 6.11.4) and a dash (–), indicating no provision, in respect of a radiotelegraphy or radiotelephony station – Appendices C to F pages 39, 42, 45 and 48 of [Ref 1] refers. The SOLAS does allow an alternative placement of SARTs in each survival craft [Ref 16]. However, this option is seldom used and is expected to be withdrawn [Ref 19] in the near future stipulating that where more than one SART

is carried, one should be stowed in a free-fall lifeboat where these are on board.

6.4.2 Two-way VHF Radiotelephones

The statutory requirement for the number of two-way VHF (hand held portable) radiotelephones on Convention ships is:

- three for passenger ships;
- three for cargo ships of 500 GRT or more; and
- two for cargo ships of less than 500 GRT.

The technical requirements for the equipment have been influenced by two IMO Resolutions – A.762(18) and of greater significance, A.605(15). The compliance date for the adoption of the latter was 1st February 1995. However, those ships where the existing equipment is VHF (as distinct from UHF) on board prior to 1st February 1992 with at least two channels, including channel 16, may continue to be used until 1st February 1999 [Ref 20].

In summary, therefore, equipment on board should have been replaced by that complying with A.605(15) by 1st February 1995 if they were:

- UHF; or
- VHF not in compliance with A.605(15) which were installed on board on or after 1st February 1992.

With reference to IMO Resolution A.762(18), the only additional requirement is that the equipment should be a highly visible yellow or orange colour or marked in this way by, for example, adhesive strips.

6.5 Flag State Requirements

Some administrations specify requirements in respect of documentation or in variation to the SOLAS Convention. In the case of documentation, administrations' requirements should be complied with in accordance with the Ship Division Survey Procedures Manual (SD SPM) [Ref 21]. The following is a summary of more significant requirements of administrations, the actioning of which should be included in the narrative of a radio survey report.

6.5.1 Danish International Ship Register (DIS)

Two copies of any Radio Certificate issued and, except for the first radio survey carried out by LR, one copy of the Radio Checklist Form 2115 or 2137 should be sent to the Danish Authorities via LR Copenhagen. At the first survey by LR the Forms 2115 or 2137 and the Record of Approved Radio Installation Form 2116 or 2138 should be sent to Headquarters (HQ).

6.5.2 Greece

A copy of the Radio Checklist Form 2115 or 2137 and, in the case of a change to the Greek Flag, a copy of the Record of Approved Radio Installation Form 2116 or 2138 should be sent to the Greek Authorities via LR Piraeus. Radio surveys on Greek Flag ships with a radiotelegraphy station should be carried out by a radio technician who additionally holds a Greek Class 'A' Radio Officer's Certificate. Where such a person is not available, the radio checklist should be signed in the normal way by the Radio Surveyor technician and countersigned by the person on board certificated to carry out radio duties.

6.5.3 Hong Kong

A copy of the Radio Certificate and a Declaration of Survey Form 1124 should be forwarded to the Hong Kong Marine Department (HKMD) via LR Hong Kong.

6.5.4 Liberia

If a radio certificate of competence has not been issued by the Liberian Authorities, then a radio survey should be part held. If this is the only item outstanding to complete the survey, a conditional Radio Certificate may be issued valid for three months.

6.5.5 Malta

A copy of the Radio Certificate should be forwarded to the Malta Maritime Authority.

6.5.6 Norwegian International Ship-register (NIS)

If a radio survey is the first by LR then a copy of the Radio Checklist Form 2115 or 2137 should be sent to HQ with the Record of Radio Installation Form 2116 or 2138. At all subsequent radio surveys carried out by LR, a copy of the Radio Checklist Form 2115 or 2137 should be sent to the Norwegian Maritime Department (NMD) via LR Oslo.

6.5.7 Panama

If a radio certificate of competence has not been issued by the Panamanian Authorities, then a radio survey should be part held.

6.6 Qualifications for Ship Radio Competence

Certificates of ship radio competence may be issued by any administration whose Government is a member of the International Telecommunications Union (ITU). In practice, this may be considered to cover all countries worldwide.

6.6.1 Radiotelegraphy

There are four categories of radiotelegraphy competence [Ref 22].

(a) Radiocommunications Operator's General Certificate, otherwise known as the Maritime Radio General Communications Certificate (MRGCC).
(b) First Class Radiotelegraph Operator's Certificate.
(c) Second Class Radiotelegraph Operator's Certificate.
(d) Radiotelegraph Operator's Special Certificate.

Holders of a radiotelegraphy certificate of competence are generally referred to as Radio Officers. The number of full time officers required to be on board a ship with a radiotelegraphy station with certification (a), (b) or (c) above are as follows:

- Cargo ship of at least 1600 GRT or a passenger ship which is on a voyage of less than sixteen hours, must have at least one Radio Officer [Ref 23].
- Passenger ship capable of carrying more than 250 passengers on a voyage of sixteen hours or more, must have at least two Radio Officers [Ref 24].
- Fishing boat equipped with a radiotelegraphy station [Ref 25], or any ship where a radiotelegraphy station is installed where it is not a statutory requirement must have at least one Radio Officer whose certification may alternatively be (d) above [Ref 26].

6.6.2 Radiotelephony

There are two categories of radiotelephony competence [Ref 27].

(a) General radiotelephony operator's certificate.
(b) Restricted radiotelephony operator's certificate.

Ship masters, officers or crew may hold a radiotelephony operator's certificate and such certificated personnel nominated to carry out radio duties may do so in addition to their other shipboard duties [Ref 28].
The number of radiotelephony operators with certification (a) or (b) above required to be on board a ship with a radiotelephony station are as follows:

- Cargo ship of at least 300 GRT but less than 500 GRT must have at least one radiotelephony operator on board [Ref 29].
- Cargo ship of a least 500 GRT but less than 1600 GRT must have at least two radiotelephony operators on board and, exceptionally, one when the duties are exclusively radio [Ref 30] although this is not a common practice.

The holder of a restricted radiotelephony operator's certificate may operate a radiotelephony station on any ship provided that the transmitter controls do not involve manual frequency adjustment and that the equipment operates to defined specifications [Ref 31]. The holder of a general radiotelephony operator's certificate or any radiotelegraphy operator's certificate other than a radiotelegraphy special, may operate any radiotelephony station on any ship [Ref 32]. Additionally, when radiotelephony is the only station on board, the designated operator may generally be a holder of a radiotelegraphy special certificate [Ref 33]. Whilst not specified in statutory regulations, administrations generally accept a GMDSS General Operator's Certificate (GOC) as qualification to operate any radiotelephony ship station.

6.6.3 GMDSS Radio

There are four categories of GMDSS radio competence [Ref 34]:

(a) First Class Radio Electronics Certificate.
(b) Second Class Radio Electronics Certificate.
(c) GMDSS GOC.
(d) GMDSS Restricted Operator's Certificate (ROC).

Categories (a) and (b) are not common, but one or the other is required in the event that on board maintenance is selected as an option ([Ref 1] section 4.4 refers). In practice, on board maintenance is not commonly selected as an option. The reason for this is the requirement to have on board a full time dedicated maintainer [Ref 35] with the consequent higher cost to the shipowner.

The SOLAS Convention requires that there be on board one certificated GMDSS radio operator [Ref 36]. For Sea Area A2, A3 and A4 ([Ref 1] Section 3.2 refers) the qualification level may be (a), (b) or (c) above [Ref 37] although it is generally the latter, namely a GOC. However, if the ship's voyages are confined to Sea Area A1, then (d) above, namely an ROC, will meet the operator requirements [Ref 38] in addition to the other categories.

Assuming on board maintenance is not specified (for which the qualification level (a) or (b) above is required) the certificated operator may be any crew member whose duties need not be primarily radio. However, during distress incidents the operator is required to have radio as his or her primary responsibility [Ref 39].

Some administrations specify a requirement different from that above in respect of operator number and their duty on board. The requirements of these administrations for which LR most commonly issue statutory Radio Certificates are as follows:

- *Cyprus* – Two qualified operators* or one exclusive qualified operator*.
- *DIS* – Two qualified operators*, except in the case of a passenger ship certified to trade in Sea Areas A1 + A2 + A3 or A1 + A2 + A3 + A4, when the Master and all navigating officers must be qualified operators*.
- *Greece* – Two qualified operators*, except where the at sea maintenance capability applies, in which case the requirement is one qualified operator* and a Radio Electronics Officer.
- *Liberia* – Two qualified operators* who are Deck Officers, or one certificated GMDSS Radio Electronics Officer dedicated to radio duties.
- *Malaysia* – As per Cyprus.
- *Malta* – Two qualified operators* on a cargo ship and three on a passenger ship.
- *Marshall Islands* – As per Liberia.
- *NIS* – One qualified operator* who must not be the master alone.
- *Panama* – Two qualified operators* who must be Navigating Officers, or one exclusive qualified operator* who is also a certificated Radiotelegraphy Officer or a suitably qualified Electronics Officer. Exceptionally, radiotelephony or radiotelegraphy certificates of competence may be accepted as an expedient, in which case the survey should be part held and an SRST issued valid for not exceeding two months.
- *Philippines* – Two qualified operators* who must be Navigating Officers.
- *Singapore* – One qualified operator* when the ship is certified to trade in Sea Areas A1 or A1 + A2, and two qualified operators* when the ship is certified to trade in Sea Areas A1 + A2 + A3 or A1 + A2+ A3 + A4, unless an exclusive qualified operator* has been nominated, in which case one qualified operator* is required.

* Qualified operator in this context is defined as a holder of a GOC or ROC as appropriate.

6.7 Ship Radio Station Licence

The provision on board of a Ship Radio Station Licence is essentially a matter between the Master and the Flag Administration. Its presence or otherwise on board does not affect the safety of the ship and in this sense its absence or invalidity does not constitute a serious breach of a radio survey inspection. Where a Ship Radio Station Licence cannot be produced or is out of date the matter should be reported to the Master. It need not, however, affect the issue

of the radio certificate in the normal way nor made a condition. The only exceptions in this respect are Malta and Cyprus flag ships whose administrations have specifically requested that the Ship Radio Licence be verified. In circumstances where on a Malta or Cyprus Flag Ship this cannot be done, or the validity has expired, then the survey should be part held and a conditional Radio Certificate issued with validity not exceeding two months.

6.8 Ship Identity Encoding

There are various items of radio equipment which have the facility for encoding the ship's identity by means of its Maritime Mobile Service Identity (MMSI), call sign or some combination of the two with, perhaps, another identifier, all depending upon the flag state's requirements in this respect. These radio items include Automatic Keying Devices (AKD), SESs, Emergency Position Indicating Radio Beacons (EPIRB) and Digital Selective Calling (DSC) equipment. Concerns have been raised by SAR authorities [Ref 40 and 41] that codings of these type are all too often not carried out on the equipment. Whilst this function is an operational matter, surveyors would be advised in view of the concerns which have been expresed to advise the Master when correct codings have not been carried out on equipment which have the facility and, if appropriate, report the survey as part held.

6.9 Radio Frequency Tolerances

The transmit frequencies for which specific tolerances [Ref 42] are required to be applied on each type of ship radio station are as follows:-

Station	Frequencies
Radiotelegraphy	(i) 500 kHz (ii) Two working frequencies in the range 405 kHz to 535 kHz (iii) 2182 kHz
Radiotelephony	(i) 2182 kHz (ii) Two working frequencies in the range 1605 kHz to 2850 kHz
GMDSS Radio	(i) 2182 kHz* (ii) For all other frequencies, tolerances may be considered acceptable when transmissions are met with the appropriate response from recipient stations
*On 1st February 1999 when the transition period for the introduction of GMDSS Radio stations will be completed, the requirement for 2182 kHz will cease in respect of GMDSS Radio stations.	

6.10 Ship Radio Station Documents

The documents specified [Ref 43] as requirements vary according to the type of ship radio station. Generally, these include the ship station licence (see also section 6.7), certificates of radio competence (see sections 6.6, 6.5.4, and 6.5.7), the radio log book, listings of call signs (such as the ITU or British Admiralty List) and coast and ship radio stations as well as the appropriate manuals for the services appropriate to the ship radio station. The log book entries should be verified and evident omissions or departures from the specified requirements [Ref 43] alerted to the Master.

6.11 Completion of the Radio Certificate and Form 'R' Documentation

The Radio Certificate (Form 1705) and Form 'R' (Form 2131) attachment, specimen examples of which are shown at appendices C to F of [Ref 1], are designed to cater for the GMDSS Radio station. This style of radio station was introduced on 1st February 1992 when the 1988 Amendments to SOLAS 1974 became effective. These amendments to the SOLAS Convention specify that, in respect of radio, ships with a keel laid prior to 1st February 1995 may comply until 31st January 1999 with either the 1988 Amendments to SOLAS 1974, or with the Regulations prior to those Amendments [Ref 44]. As a consequence, provision has been made at Section 4 of the Form 'R' for the old style radiotelegraphy and radiotelephony station. This apart, the style of the forms are such that not all the entries will be applicable to a radiotelegraphy or radiotelephony station.

Specific points relating to the completion of the radio certificate and Form 'R' are as follows.

6.11.1 In respect of ships with a radiotelephony or radiotelegraphy station

The concept of "Sea Areas" do not apply in respect of radiotelegraph and radiotelephony stations. Hence, a dash (–) should appear in the entry on the Radio Certificate against "Sea areas in which ship is certified to operate .....". Similarly, a dash (–) should appear in the last box in Section 1 of the Form 'R' ("Minimum number of persons with required qualifications to operate.....") because this entry is applicable only to GMDSS Radio requirements. The remaining Sections 2 and 3 of the Form 'R' relate entirely to GMDSS Radio requirements and hence a dash (–) should appear in each box with the exception of 2.3.1 and (whichever is appropriate) 2.4.1 or 2.4.2, although almost invariably this will be the former. The reason for the entries at Sections 2.3.1, and 2.4.1 or 2.4.2, is that the items indicated by these boxes (NAVTEX Receiver and Satellite EPIRB) are GMDSS Radio requirements which are also applicable to ships with a radiotelegraphy or radiotelephony station [Ref 45]. Section 4.1 or 4.2, as appropriate, should be completed in full.

Instances have occurred when port inspectors (as well as some classification societies and administrations) require that boxes in Section 2 of the Form 'R' in addition to 2.3.1

and 2.4 should be completed, for example, in respect of boxes 2.6, 2.7, 2.8 and sometimes other boxes. This is incorrect! The 1988 Amendments to the 1974 SOLAS clearly states that a ship's radio requirements should either comply with the Amendments, or the requirements prior to the Amendments [Ref 46]. There is no provision in the SOLAS which allows part compliance to the Amendments and part compliance to the arrangements before the Amendments. The only exception is in respect of the NAVTEX Receiver and Satellite EPIRB [Ref 45].

Should the matter arise of boxes in section 2 of the Form 'R' being completed other than in respect of the NAVTEX Receiver and Satellite EPIRB, it is suggested that it should be challenged by requesting where in Chapter IV of the 1988 Amendments to the 1974 SOLAS Convention it is stipulated that the equipment so indicated should be installed on a ship with a radiotelegraphy or radiotelephony station.

6.11.2 In respect of ships with a GMDSS Radio station

All the items on the Radio Certificate are applicable to be completed as appropriate and, for the most part, the responses required are self evident. In the majority of cases, the appropriate entry against "Sea areas in which ship is certified to operate....." is "A1+A2+A3". In the minority of cases where this does not apply, then the appropriate entry will be one of the other three alternatives of "A1+A2+A3+A4", "A1+A2" or just "A1", although in the case of the latter, this is rare with the type of ships on which LR carries out surveys.

With respect to the Form 'R', the appropriate entries in Section 1 are self evident. The entry against "Minimum number of persons with required qualifications to operate....." should be "One" (the Convention requirement specifies that "..... any one .....(qualified operator)..... shall be designated.....") [Ref 36] although as mentioned in paragraph 6.6.3 certain administrations do not comply with the SOLAS in this respect and have stipulated their own "minimum". The reason for their non compliance with the SOLAS in this regard is a likely misunderstanding of the wording of this 1988 Amendment or perhaps some confusion with the radiotelephony station requirement where a ship of 500 GRT or more is to have two certified operators.

6.11.3 Form 'R' Serial Number

The Form 'R' serial number to be used is the LR number immediately followed by an oblique stroke and two digits incremented by one according to the number of Form 'Rs' issued with previous Radio Certificates, viz. /01, / 02, / 03, etc.

6.11.4 Entries on the Form 'R'

The quantities shown on the Radio Certificate and Form 'R' relate to the minimum statutory requirement for radio. Thus, in respect of a ship with a GMDSS Radio station, "1" should appear against "Ship's radar transponder" at Section 2.6 because that is the radio requirement [Ref 17] (the requirement for two radar transponders applies to the Safety Equipment certification process [Ref 16]). Where equipment is not provided, or an entry is not applicable, then a dash (–) should be indicated as appropriate.

With reference to the specimen examples in appendices C to F of [Ref 1] the applicability of each section of the Form 'R' is:

Form 'R' Section	Applicability
1	Applicable to all types of radio station except for the "Minimum number of persons with required qualifications to operate the radio installation" which is applicable only in respect of a GMDSS Radio station. Hence, in respect of a radiotelegraphy and radiotelephony station a "dash" (–) should be entered.
2 and 3	Applicable to GMDSS Radio requirements in accordance with the 1988 amendments to SOLAS 1974.
4.1	Applicable to radiotelegraphy stations in accordance with SOLAS 1974.
4.2	Applicable to radiotelephony stations in accordance with SOLAS 1974.

6.12 Emergency Position Indicating Radio Beacon (EPIRB)

Since 1st August 1993, all Convention ships have been required to carry a satellite EPIRB [Ref 45]. However, the Convention does have a provision which allows a ship with a GMDSS Radio station which sails exclusively in Sea Area A1 ([Ref 1] Section 3.2 refers) to have a SART which additionally has an alerting facility using VHF DSC channel 70 [Ref 47]. However, the author is not aware of such an equipment having been manufactured for the SOLAS Convention ship market.

With respect to the satellite EPIRB, the Convention offers the choice between the COSPAS/SARSAT satellite system with alerting on 406 MHz or the INMARSAT satellite system with alerting a 1.6 GHz [Ref 48], although the latter cannot be used on the few ships whose voyages include Sea Area A4 ([Ref 1] Section 3.2 refers). The reason for this is that Sea Area A4 is outside the INMARSAT footprint coverage. In fact the EPIRB infrastructure in the INMARSAT satellite system has been plagued with difficulty and delay to such an extent that the author is not aware of any 1.6 GHz EPIRBs which have been installed on ships for which LR arranges radio surveys.

Thus, whilst the Convention makes provision for a choice between three types of EPIRB (VHF DSC channel 70, 1.6 GHz or 406 MHz) in practice surveyors are only ever likely to come across the 406 MHz type. For this reason the provision made for the INMARSAT and VHF EPIRB in the Radio Certificate documentation ([Ref 1] page 39 at Section 2.4.2 and 2.5) will almost invariably have a dash (–) against the entry items.

The UK Marine Safety Agency (MSA) have identified the more common faults relating to EPIRBs. These are:

(a) The EPIRB left in a de-activated condition during voyages by being either switched off or otherwise disarmed.

(b) Securing the EPIRB to the ship either by a rope or its lanyard, the latter's purpose being to tether the equipment to the survival craft so ensuring that the two remain together.
(c) Overdue batteries.
(d) Hydrostatic Release Unit (HRU) servicing or replacement overdue.
(e) On board repairs to the HRU by other than an accredited technician thus making it inoperable.
(f) Awkward access to the mounting position which may cause difficulty in recovering the EPIRB should there be a need to take it to a survival craft in a hurry. Such inaccessibility is sometimes deliberate as an anti theft measure, particularly on the smaller Convention ships.
(g) Whilst in port, stowage in the wheelhouse or a cabin is a common anti theft measure on smaller Convention ships with the risk of properly re-mounting the equipment when the ship puts to sea being overlooked.
(h) Seized up release mechanism as a result of routine maintenance not being carried out.
(i) It may be acceptable on certain ships, such as ferries, for the EPIRB to be padlocked to its mounting where experience has shown that certain types of passengers, such as football supporters, have a predilection to throw unsecured equipment over the side. Such padlocking need not necessarily affect the EPIRB's float free capability, but it could prevent it being taken to a survival craft in an emergency. Hence, where a padlocking policy has been adopted for good reason, there should be a "break glass" box in close proximity containing the key.
(j) An equipment registered with another ship or not registered at all.
(k) Illegible identification details due to weathering by sun or salt spray.
(l) Failure to operate on self test, often caused by low voltage as a result of coating on the cathode of the lithium battery.
(m) Ingress of water through cracks or faulty seals.

For the most part all these items are operational matters capable of being put right by the responsible person on board during the course of the radio survey. There may be the occasion when such an item will justify a condition being placed on the issue of a statutory certificate. Whilst in the majority of cases this will not be necessary because the matter is corrected during the course of the survey, it should, nevertheless, be pointed out to the Master so he may be aware of the level of attention needed for EPIRBs to fulfil the function for which they are intended.

6.13 NAVTEX

A NAVTEX receiver is a statutory requirement on all Convention ships [Ref 45] which enter waters served by a NAVTEX broadcast service [Ref 49]. In practice this covers the vast majority of Convention ships although there are a minority for which the requirement will not apply. For example, a Convention ship whose voyages do not extend beyond Australasia may not have a statutory obligation to install a NAVTEX receiver as administrations in the region (including Australia and New Zealand) do not provide a NAVTEX broadcast service and, at the time of writing, have no plans to do so.

Country	NAVTEX Coast Station	Position	Range (NM)	Transmission time (UTC)
Belgium	Oostende Radio	51 11N 02 48E	55	0248,0648,1048,1448,1848,2248
Iceland	Reykjavik Radio	64 05N 21 51W	550	0318,0718,1118,1518,1918,2318
Netherlands	Netherlands Coast Guard	52 06N 04 15E	110	0348,0748,1148,1548,1948,2348
Norway	Bodo Radio	67 16N 14 23E	450	0333,0733,1133,1533,1933,2333
	Rogaland Radio	58 48N 05 34E	450	0148,0548,0948,1348,1748,2148
	Vardoe Radio	70 22N 31 06E	450	0300,0700,1100,1500,1900,2300
Sweden	Stockholm Radio	64 28N 21 36E	300	0000,0400,0800 (weather forecast), 1200 (ice report) 1600, 2000 (weather forecast)
	Stockholm Radio	55 29N 14 19E	300	0330,0730 (weather broadcast) 1130 (ice report), 1530, 1930 (weather forecast), 2330
	Stockholm Radio	59 16N 18 43E	300	0030, 0430, 0830 (weather forecast), 1230 (ice report), 1630, 2030 (weather forecast)
United Kingdom	Cullercoats Radio	55 02N 01 26W	270	0048,0448,0848,1248,1648,2048
	Portpatrick Radio	54 51N 05 07W	270	0130, 0530,0930,1330,1730,2130
	Niton Radio	50 07N 05 40W	270	0018,0418,0818,1218,1618,2018
Russian Federation	Murmansk Radio	68 58N 33 05E	140	0120,0520,0920,1320,1720,2120
	Arkhangelsk Radio	64 33N 40 32E	280	0200,0600,1000,1400,1800,2200

Figure 15
NAVTEX Broadcasts available in Northern Europe

A NAVTEX receiver provides a simple means of receiving MSI in coastal waters ([Ref 1] Section 2.5 refers). These include navigation warnings, weather information as well as a means of alerting ships to a distress incident. Common faults with the on board equipment are for the most part operational matters as follows:

(a) The equipment being left switched off when sailing in an area served by a NAVTEX broadcast service.
(b) Faint print on the paper message roll.
(c) Inadequate paper roll supply.
(d) A model of equipment not designed to provide a print copy. Paperless equipments are available on the market and whilst they may be acceptable for small pleasure craft and other non Convention ships, ships covered by the Convention are required to have a paper print record [Ref 50] at the time the broadcast takes place.

An increasing number of administrations with coast lines have, or plan to have, NAVTEX coast stations. Northern Europe probably has the most comprehensive NAVTEX broadcast coverage in the world with eight administrations contributing to the service as shown in Figure 15.

A NAVTEX Coast Station is planned to be established in Ireland with transmissions at 0340, 0740, 1140, 1540, 1940 and 2340. At the time of writing no opening date was available or location. All the NAVTEX broadcast transmissions are in the English language.

7 Consequences of Advances in Maritime Communications

7.1 Review of the GMDSS

The greatest impact which INMARSAT has had on the shipping industry world-wide in the latter years of the 20th century has been the introduction of the GMDSS. Without INMARSAT there would have been no GMDSS. This is not consequent solely on the communications technology offered through the INMARSAT system, but also on the significant role played by its Directorate in developing events in the IMO and as an opinion former generally within the industry and government bodies world-wide.

The GMDSS presented a radical departure in safety radio communications. In devising the system, the IMO stipulated specific capabilities which the GMDSS must have [Ref 51] and it was left to the maritime telecommunications industry to develop on board equipment which fulfilled the criteria. The capabilities demanded of the system were laid down as follows:

- transmitting ship to shore distress alerts by at least two separate and independent means;
- receiving shore to ship distress alerts;
- transmitting and receiving ship to ship distress alerts;
- transmitting and receiving search and rescue co-ordination communications;
- transmitting and receiving Maritime Safety Information (MSI);
- transmitting and receiving general radio communications; and
- transmitting and receiving bridge to bridge communications.

These requirements introduced a new concept for safety radio communications, namely:

- dispensing with all demarcation based on the size or category of ships covered by the SOLAS Convention;
- a switch from the concept of ship to ship communication for distress alerting to that of ship to shore;
- on board locating to facilitate search and rescue; and
- the facility for communicated MSI for the areas in which the ship is sailing.

Alas, there are certain areas where the IMO stipulation for the GMDSS are not fulfilled [Ref 52] and where this is the case it can be attributed to an acknowledgement of realities - operational and financial. For example, the requirement to initiate ship to shore alerts by at least two separate independent means is not necessarily applied where the means is the INMARSAT service. It is permissible to have distress alerts by means of an INMARSAT EPIRB and an INMARSAT SES or, indeed, two SESs. The reality is the inherent reliability of the INMARSAT system. To adhere slavishly to a functional requirement when the statistical evidence shows that the need for doing so is doubtful would make little sense. Similarly with respect to the

receipt of MSI requirement. This is met by means of the NAVTEX and EGC services but ships in Sea Area A4 ([Ref 1] Sections 2.5 and 3.2 refers in respect of NAVTEX, EGC and GMDSS Sea Areas) may not be able to receive either. The reality is that few ships sail in the polar regions (Sea Area A4). To adhere doggedly to the MSI requirement would entail the extension of INMARSAT coverage to the polar regions, perhaps necessitating two additional satellites, plus, most likely, two spares. At a cost of US $80m per satellite plus around US $70m launch costs for each, the arithmetic speaks for itself.

As far as government administrations are concerned however, the contribution in some areas of MSI has been described as lethargic [Ref 52] in following through commitments to the GMDSS. This similarly applies to the provision of facilities at coast radio stations to enable A1, and indeed A2, Sea Areas to be established.

7.2 False Distress Alerts

A problem which has coincided with the increasing use of automated maritime communications systems in recent years has been the rise in the frequency of false alerts. This has prompted the USCG to comment on the strains placed on their resources [Ref 53]. Also, the UK MSA has warned that if the high level of false alerts continues, the chances of them coinciding with a real distress situation is very real with the possibility that SAR services could be delayed in responding to a genuine distress with resultant tragic consequences[Reg 54]. The following advice based on UK MSA guidelines on radio operator practice may be helpful to LR staff in providing guidance to clients.

7.2.1 Owners, Masters and Skippers

Masters of all types of sea going vessels should make sure that all who may be required to send distress alerts are knowledgeable in the operation of all radio equipment on the ship. Instructions should be given periodically on board to all relevant crew members by the person responsible for communications. To reduce the chance of false alerts, routine testing of GMDSS equipment should only be undertaken under the direct supervision of the person designated on board to have responsibility for radio communications during distress incidents. The following is advice in respect of the operation of DSC equipment, EPIRBs and Inmarsat C satellite terminals.

7.2.2 Acknowledgement of DSC Distress Alerts.

Acknowledgement of an MF or HF DSC distress alert can lead to the subsequent broadcast of a large number of unnecessary DSC calls. The following procedures should therefore be followed:

(i) A ship operating in an A2 area, that is within the MF R/T (radiotelephone) coverage of at least one MF coast station in which continuous DSC alerting is available, which receives an MF DSC distress alert on 2187.5kHz, should not transmit a DSC acknowledgement, notwithstanding any prompt on the DSC equipment to do so. It should be assumed that the alert will have been heard and acknowledged by a coast station despite it not being obvious to the receiving ship which may be beyond reception range of the coast station. Thus, following receipt of a DSC distress alert or distress relay, radio operators should listen on 2182kHz for further distress traffic and, subject to the Master's instructions, acknowledge using R/T. Assistance should then be rendered as required and appropriate.

(ii) A ship operating outside of an A2 sea area which receives a distress alert and which is, beyond doubt, in its vicinity, should send an acknowledgement as soon as possible by using R/T on 2182kHz. If further DSC distress alerts are heard from the same source, then a DSC acknowledgement may be sent. RCCs should be informed through a coast station or CES and assistance rendered as required and appropriate. The flow chart at Figure 16 shows the procedure to be followed.

(iii) On receipt of an HF DSC distress alert, no acknowledgement should be sent from the ship. Instead, the Radio Operator must listen out on the radiotelephone and radiotelex distress and safety traffic frequencies associated with the distress and safety calling frequency on which the alert was received.

(iv) If subsequent HF DSC distress alerts are received, or it is clear there has been no acknowledgement by a coast station, then the ship must relay the distress alert.

7.2.3 Silencing alerts sent inadvertently

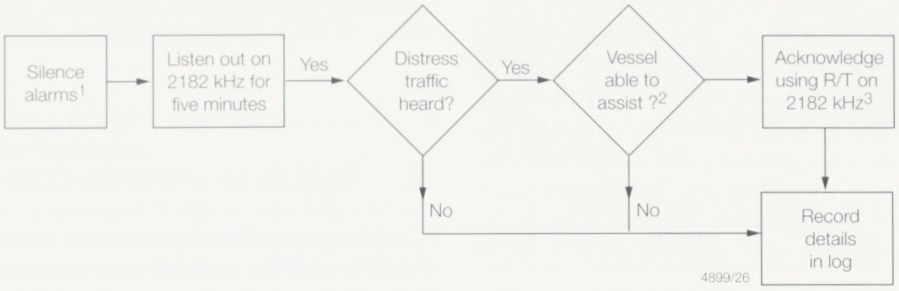
(i) If an MF DSC alert is sent inadvertently, then a message should be transmitted on 2182 kHz as follows: "MAYDAY, hello all stations (ship identity number and ship name) cancel my DSC distress alert of (time) transmitted on 2187.5 kHz". If the inadvertent distress alert has been acknowledged by an RCC, then a message should be sent to that RCC as follows: "MAYDAY (name of RCC followed by the ship identity number and ship name) cancel my DSC distress alert of (time) transmitted on 2187.5 kHz".

(ii) If an HF DSC alert is sent inadvertently, then the same procedures should be followed at 7.2.3(i) using the appropriate HF frequencies.

7.2.4 Inmarsat C

All Inmarsat-C SESs are designed to make it simple to send a distress alert. Thus, extreme care is needed when reviewing the contents of the distress message generator to ensure that the menu is exited without transmitting a distress message.

The distress alerting function on an Inmarsat-C is tested during its Performance Verification Test (PVT). During the PVT, a special test distress message is substituted for the live distress message which remains valid for about one minute. Although much of the PVT is automated, it is desirable for the operator to remain in attendance at the terminal to test the distress alert at the correct time, usually prompted by the terminal. This reduces the possibility of initiating the distress test after the terminal has returned automatically to live test mode. If an INMARSAT alert is sent inadvertently, then the ship should call back to the relevant CES as follows: "Cancel my Inmarsat-C distress alert (ship name and identity number) of (time)".



1 **DO NOT SEND A DSC ACKNOWLEDGEMENT**. It can be assumed that the DSC call will have been heard and acknowledged by a Coast Station whose transmissions may be out of range of your own ship. If further DSC distress alerts are heard from the same source and the vessel in distress is, beyond doubt, in the vicinity, a DSC acknowledgement may the be sent to terminate the call and a Rescue Co-Ordination Centre informed .

2 If it is clear the vessel or persons in distress are not in the vicinity and/or other craft are better placed to assist, superfluous communications which could interfere with Search and Rescue activities are to be avoided . Details should be recorded in the appropriate Log Books.

3 The ship should establish communications with the station controlling the distress as directed and render such assistance as required and appropriate

Figure 16
Procedure for responding to a distress alert on DSC 2187.5 kHz.

7.2.5 Registration of EPIRBs

It is essential that the encoded details of ships' satellite EPIRBs which are registered in databases accessible 24 hours per day by authorities responsible for organising SAR services. In the event of an emergency, this information will help the DSS to identify the ship in distress and obtain other information in order to respond appropriately. Any change to the details of the ship should be notified to the EPIRB registration database.

7.2.6 Care of EPIRBs

EPIRBs must be installed in accordance with the manufacturer's recommendations and by qualified personnel. They must be installed in a proper location so they can float free and automatically activate if the ship sinks. Care must be taken that they are not tampered with or accidentally activated. Unmanned vessels under tow should have EPIRBs switched off or removed from the vessel. Many EPIRBs have lanyards to secure the EPIRB to a life raft, lifeboat or person in the water. These lanyards are not to be used for securing the EPIRB to the vessel. Such action will clearly prevent the device from floating free and transmitting.

Once an EPIRB is activated, whether accidentally or intentionally, the ship should make every reasonable attempt to communicate with the DSS by other means to advise them of the situation. The EPIRB should be left on until the SAR authority is contacted. This will allow the vessel to be located and prevent unnecessary searching.

7.2.7 Manufacturers, Suppliers, Installers and Instructors

It is recommended that suppliers, installation personnel and instructors have knowledge of the GMDSS and the consequences of transmitting a false distress alert. After any GMDSS equipment has been installed, the necessary operating instructions should be given to the appropriate personnel on board, specifically pointing out the operational procedures for the equipment in question. It is important that operating instructions should be as clear and precise as possible. Maintenance instructions should be separated from operational instructions.

Radio equipment used for transmitting distress alerts should be so designed that it will not be possible to transmit a distress alert unless the distress button is deliberately pressed. The button should be protected against inadvertent operation and require two independent actions to initiate a distress alert transmission. The activation of any alert should be indicated visually or acoustically to indicate clearly that the equipment is transmitting an alert until manually deactivated.

7.3 Take Up of GMDSS Radio by Ship Owners

The IMO has issued a number of papers expressing concern about the slow take up of GMDSS Radio stations by shipowners. The seven year transition period agreed by the IMO to allow owners to convert their ships extended from 1st February 1992 until 31st January 1999, after which all ships covered by the 1974 Convention are required to have GMDSS Radio stations. The penetration of GMDSS Radio stations during this period has been far from linear, as is evidenced by IMO data which showed that only some 25% of European flag ships had GMDSS Radio stations at the half way point in the transition period with the world-wide figure estimated at 15% [Ref 55]. The reason for the skew in take up distribution can no doubt be attributed to a number of factors, not least lethargy among some flag

administrations [Ref 52]. This is very much contrary to the expectation of events in the 1980s. At that time the general view was that the financial benefit of being able to dispense with the on board full time Radio Officer would encourage a rapid and early take up of the GMDSS Radio option. The only concern which was expressed in those days was with regards to cargo ships of less than 1600 GRT where no such financial incentive was available because there is no statutory requirement for such ships to carry a Radio Officer.

At the time of writing, the only trend pattern to have emerged with respect to the rate of GMDSS Radio take up seems to be related to the flag of the ship. A few national fleets, such as Australia [Ref 56], were well advanced in the conversion programme considerably ahead of the deadline date.

Logistically it is clearly better to have a steady take up of GMDSS Radio stations, so avoiding a bunching up towards the end of the transition period of 31st January 1999. This not only applies to radio equipment provision, but also college course availability for deck officers seeking GMDSS operator certification. It is therefore in ship owners' ultimate interest not to delay the fitting of GMDSS Radio stations. In this respect a paragraph is included in the covering letter accompanying all radio certificates for radiotelegraphy and radiotelephony stations reminding that the radio installation must be replaced by a GMDSS Radio station before 1st February 1999 [Ref 57]. All surveyors in LR offices world-wide are urged to encourage ship owners and managers to install GMDSS Radio stations well before the deadline date.

Depending on the type of equipment already on board, the price range for conversion to a GMDSS Radio station has been quoted [Ref 58] to be as little as $US 2,000. However, equipping a ship from scratch is similarly quoted in the range from $US 7,000 to $US 42,000. Additionally, the college training expenses and examination fees for the GMDSS Radio certification are around $US 1,200 per person. But it is important to highlight that these costs may be offset by the saving in recurring costs of full time Radio Officers on the crew complement. A further factor which has been used [Ref 59] to encourage owners to switch to GMDSS Radio stations earlier rather than later is that price will inevitably be dictated by demand and this will likely be highest immediately prior to the date when GMDSS Radio stations become compulsory on 1st February 1999. Every opportunity should be taken by LR offices to encourage owners to convert on board radio stations to GMDSS [Ref 60].

8 Into the 21st Century

8.1 Expansion in Mobile Communications

Over the past decade there has been a considerable growth in the availability of mobile communications. This has not been confined to the services offered by INMARSAT. Mass market applications became available with various "bleeper" systems which alert someone to call in by telephone on a pre-arranged number. Later followed more sophisticated systems which could convey a written message. There then followed a considerable expansion in the mobile communications market with the introduction of cellular 'phone systems.

Whether one considers it a curse or a blessing, the market for mobile telecommunications is set to expand. The rate of future growth depends upon whose forecasts one chooses to believe, but all generally predict that hand held mobile 'phone systems will have a greater user base than "hard-wire" telecommunications networks at some future date. This is the more remarkable when set against the fact that it will never be feasible (for a mix of technical, economic and practical reasons) for the technology upon which existing cellular mobile 'phone systems are based to provide service to some 60% of the World's population, 80% of its land mass, and all sea areas other than at the coastal fringes. Reaching those parts which cellular 'phone systems cannot has been exercising the entrepreneural ingenuity of a number of organisations seeking to justify venture capital investment. What these organisations generally agree upon is that in order to serve those regions inaccessible to existing cellular technology will:

(a) need to be based on some kind of satellite based telecommunications system;
(b) unlikely be deliverable at prices competitive with existing cellular 'phone systems; and
(c) as a consequence, be a complement to existing cellular 'phone systems and hence need to have dual access to both.

Dual access to satellite and cellular systems presents an added challenge when even compatibility between different cellular systems have yet to be resolved [Ref 61]. At the time of writing, cellular 'phone compatibility remains a contentious issue with which the ITU are seeking to grapple. Global Standard Mobile telephones (GSM) technology has been adopted by most countries where it has become well entrenched with two significant exceptions – the USA and Japan. US operators have invested heavily in what they consider to be a superior standard; Code Division Multiple Access (CDMA), and yet a third standard has been adopted in Japan called Personal Handyphone.

Clearly, if cellular 'phone compatibility is not achieved by agreement on a common World standard, then it will be either by force of strength or multimode access 'phones. Such multimode access will additionally need to address the Global Mobile Personal Communications by Satellite

(GMPCS) systems, standards for which were addressed by an ITU Policy Forum in October 1996.

8.2 Alternative Mobile Telecommunications Satellite Systems

Technical studies undertaken by the various organisations seeking to provide a hand held satellite 'phone service generally conclude that there are three systems of satellite deployment which would be feasible for such a service. These are the:

(a) geostationary satellite system currently used in the INMARSAT as well as other major telecommunications services with relatively few (three or four) satellites deployed 36,000 km above the earth;.

(b) Intermediate Circular Orbit (ICO) system with between six to twenty smaller sized satellites 8,000 to 12,000 km above the earth; and

(c) Low Earth Orbit (LEO) system with forty to seventy still smaller sized satellites up to 2,000 km above the earth.

The choice of system depends upon varying cost, both operational and technical, benefit analyses. The geostationary system requires large traffic carrying capacity and, therefore, high cost satellites both in terms of hardware and launch delivery. A perceived operational disadvantage of the Geostationary system is the transmission delay due to the satellite path link of some 72,000 km which may be unsettling for the type of user in the target hand held 'phone market. This problem does not arise with the LEO system, although many more satellites, albeit at much lower cost in terms of hardware and launch delivery, are required in order to gain good global coverage as well as to avoid loss of line of sight with the satellite caused by "shadowing" from mountains and even tall buildings. The ICO system steers the middle course between the relative advantages and disadvantages of the geostationary and LEO systems.

There are additionally severe technical constraints imposed by the physical nature of the hand held instruments. Their transmit and receive efficiency are very much impaired compared with CESs and Inmarsat-A and B SESs with their directional dish aerials beamed at the satellite and greater transmit power. The relative inefficiency of the hand held 'phone instrument has to be compensated by greater satellite power and efficiency in detecting signals to overcome the constraints imposed by a small omni-directional stub antenna. These constraints detract, to a large extent, from the feasibility of a geostationary satellite system for the hand held 'phone market.

8.3 Hand Held 'Phone Systems Under Development

Of a number of organisations which have sought to develop a hand held 'phone system based on satellite technology, two have emerged as front runners; the Iridium and ICO Global Communications consortia. Both predict that they will commence service around the turn of the century.

The Iridium system was developed by Motorola's Satellite Communications Division. Based in Washington DC, the consortium comprises leading manufacturers in the aero space industry world wide. Iridium will use 66 satellites deployed in the LEO system in six orbital planes at a height of 780 km [Ref 62].

ICO Global Communications was born out of the INMARSAT Organisation. Based in London, the ICO Global Communications consortium comprises leading national and international telecommunications service providers. ICO Global Communications will use twelve satellites deployed, as its title implies, in the ICO system in two orbital planes at a height of 10,355 km [Ref 63].

Figure 17 illustrates the satellite deployment around the earth in the Iridium and ICO Global Communications systems with comparative information between the two. The significant differences in this comparative information is a function of the height of the satellites above the earth. The higher the satellites the greater is the span of earth they can "see" and hence the fewer needed. However, the fewer satellites there are the higher is their unit cost, both in terms of capacity and launch consequent from their greater weight and higher altitude. Thus, the financial trade off between the two systems is a greater number of lower cost (launch and unit costs) satellites against a smaller number of higher cost (launch and unit costs) satellites.

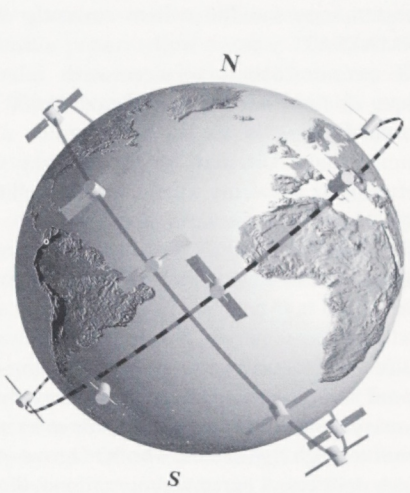
8.4 Implications for LR

Much of LR's function and justification is the certification of fitness over broad areas of activity. In order to carry out this function, comprehensive documentation built up over many years, which is in a continuing state of adaption and expansion, is required to be available for reference. Similarly, a timely and efficient certification issue process must be available. It is clearly demonstrable that the bringing together of these requirements is generally met whilst the effort required to do so increases the more difficult the physical access is to where fitness is required to be assessed. With respect to ship surveying, access to class and statutory data as well as certification will be easier in ports such as Rotterdam and Hamburg than, for example, in remote east African ports. This does not mean that greater data and certification accessibility would not benefit surveyors' work in Rotterdam or Hamburg. Clearly it would. In that respect the data download potential via a mobile telecommunications satellite system has enormous scope for easing the work of all field surveyors and bringing accessibility on a par wherever they are located.

Guglielmo Marconi gave the World's first public demonstration of "wire-less" transmission just over 100 years ago on 27th July 1896 from a building on the site where BT Corporate HQ is now located in London. Since that first public message, which travelled no more than 300 metres, the advances in telecommunications have been staggering and continue to be so. It has been estimated that more computer power is available in the average desk Personal Computer than was available to NASA when it landed men on the moon, and that microprocessor

performance doubles every eighteen months or so [Ref 64]. It takes little imagination to appreciate the potential to enable field surveyors, wherever located in the World, to have ready access to all data needed to carry out any survey and issue the appropriate certificate of fitness on the spot. The technology to do so is available now. Systems such as Iridium and ICO Global Communications will provide the vehicle.





Orbital system	LEO	ICO
Number of satellites	66	12
Number of orbital planes	6	2
Orbital height	780km	10,355km
Inclination of orbital plane to equator	86.4°	45°
Manufacturer	Lockhead Missiles and Space Corporation	Hughes Space and Communications

Figure 17
Iridium and ICO Global hand held satellite communications systems

9 Acknowledgements

The various information sources which contributed to this Paper are gratefully acknowledged. In particular the information readily made available by INMARSAT in their Design and Installation Guidelines, Service Definition Manuals and Technical Requirements Document as well as the photograph at Figure 3 is greatly appreciated. Acknowledgement also goes to Michelle Bruce and Mandy Belcher who so stoically, and without demur, contended with typing the drafts.

Glossary of Terms and Abbreviations

AA:	Accounting Authority. An organisation appointed by a ship owner or manager to co-ordinate the payment of maritime telecommunications user fees among the various coast stations which have provided the ship with service.
AAIC:	Accounting Authority Identity Code. Identifies the ship for telecommunications billing purposes.
AKD:	Automatic Keying Device. A device which forms part of a W/T station to transmit in morse code the ship's unique identification (call sign) and other data without human intervention in the event of a distress situation.
Amd:	Amendment – in respect of the SOLAS.
AOR-E:	Atlantic Ocean Region East.
AOR-W:	Atlantic Ocean Region West. Both the AOR-E and W are designated satellite footprints in the INMARSAT system.
ARPA:	Automatic Radar Plotting Aid. A navigation aid which forms part of the Safety Equipment certification process.
Astro Space:	Builders of the 3rd generation of INMARSAT satellites. Astro Space is a part of the Lockhead Martin Corporation.
BT:	British Telecom. The UK company which at the time of writing ran all coast stations in the UK offering public maritime telecommunications correspondence services and, until 31st October 1996, carried out ship radio inspection services on behalf of the MSA. On 1 November 1996 the agency for this latter function was passed to GEC Marconi Communications Marine Division until 31st October 2001 when the agency may be offered for tender again.
CCITT:	International Telegraph and Telephone Consultative Committee.
CDMA:	Code Division Multiple Access. Mobile 'phone technology favoured by US telecommunications operators - see GSM and Personal Handyphone.

CES: Coast Earth Station. A telcommunications station via which public correspondence traffic is passed over the INMARSAT system.

COMSAT: A US company which, at the time of writing, was the largest provider of public maritime telecommunications correspondence services via the INMARSAT system in the US. COMSAT also operates CESs outside the US.

CSS: Co-ordinator Surface Search. An on scene communications term used in SAR operations.

DID: Destination Identifiers. Data required during the SES commissioning procedure.

DIG: Design and Installation Guidelines. INMARSAT publication for installing SESs.

DIS: Danish International Ship-register.

DSC: Digital Selective Calling. The means of distress alerting in the GMDSS without the use of satellites. Calls may be made by an MRCC to an individual ship, or to ships in a designated geographical area.

DSS: Distress and Safety Services. Also, Distress and Safety System.

ECS: Electronic Commissioning System. A means of commissioning SESs into the INMARSAT system.

EGC: Enhanced Group Calling. A system of selective broadcast calls in the INMARSAT system to defined groups. These may be based on geographical area (IMO, satellite footprint etc.), flag of registry, shipping company etc.

EMC: Electro Magnetic Compatibility. Relates to electrical interference between various equipments on board and ashore.

EPIRB: Emergency Position Indicating Radio Beacon. A distress alerting beacon which, when activated, emits signals from which the position and identity of the ship may be determined.

ESA: European Space Agency. Governments sponsored organisation dedicated to the development of space technology including the launching and manufacture of satellites on a commercial basis. Was formerly the European Space Research Organisation.

EUTELSAT: European Telecommunications Satellite Organisation. A consortuim of European national telecommunications service providers who supply the satellites and control systems to facilitate to the provision of satellite communications for public correspondence.

FRLP: Forward/Return Linked Pair. Number allocated by INMARSAT and programmed into an Inmarsat-B, C or M SES as a requirement of the commissioning procedure.

GCBS: General Council of British Shipping. A UK ship owners' organisation which represents the interests of British Shipping.

Geostationary: The height above the equator (36,000 km) at which a satellite travels at the same rotational speed as the earth and hence remains in the same position relative to the earth.

GF: Gold Franc. A unit of exchange used as a common basis of charging for telecommunications services by most coast stations in addition to the national currency of the country in which the station is located.

GMDSS: Global Maritime Distress and Safety System.

GMPCS: Global Mobile Personal Communications by Satellite. World technical standard to achieve compatibility between hand held satellite 'phone systems.

GOC: General Operator's Certificate. The certificate of qualification issued by Administrations to mariners who have demonstrated competence in the operation of a GMDSS Radio station for all the GMDSS Sea Areas following a course of instruction and written and practical examinations.

GPS: Global Positioning Satellites. A navigational aid using fixes on satellites.

Ground Segment: Term used in the satellite telecommunications services to define that element which is earth bound. In the INMARSAT service this includes CESs, SESs and other earth bound stations and systems whose function is to control the integrity of the service.

GRT: Gross Registered Tonnage. One of the SOLAS determinates for the type of communications station required to be installed on a ship.

HF: High Frequency. Radio spectrum generally defined in the range 3 to 30MHz.

HKMD: Hong Kong Marine Department.

HQ: Headquarters.

HRU: Hydrostatic Release Unit. In the GMDSS relates to the release mechanism for such equipment as EPIRBs and SARTs.

ICO: Intermediate Circular Orbit. Satellites positioned in orbital mode some 8,000 to 12,000 km above the earth. Six to twenty satellites would be required to provide global telecommunications coverage depending on the height of orbit.

ICS: International Chamber of Shipping. A ship owners' organisation to represent their interests.

ID: Identity Number. In the INMARSAT service the ID is effectively the telephone, fax or telex number of the ship.

IEC: International Electrotechnical Commission. A standard setting body.

IHO: International Hydrographic Organisation.

IMCO: International Maritime Consultative Organisation. The former name for the IMO.

IMN: INMARSAT Mobile Number. A unique number assigned to Inmarsat-C and M SESs by the National RO as a part of the commissioning process.

IMO: International Maritime Organisation.

INMARSAT: International Mobile Satellite Organisation. Formerly the title was the International Maritime Satellite Organisation but was changed to reflect the wider role of INMARSAT beyond maritime communications. However, the acronym INMARSAT was retained.

Inmarsat-A: The first maritime satellite service which became operational in 1976 as the Marisat service which INMARSAT inherited in 1982. The service offers good quality voice, fax, data and telex.

Inmarsat-B: Introduced in 1994, the service offers the same facilities as Inmarsat-A but in the digital mode with better quality and more efficient use of radio spectrum. Inmarsat-B will eventually replace Inmarsat-A although the two standards will co-exist until well into the 21st century.

Inmarsat-C: A non voice messaging and data service utilising relatively low cost small sized on board equipment. Inmarsat-C was introduced in 1991.

Inmarsat-M: Introduced in 1992 to provide a relatively low cost voice service using compact on board equipment. Mainly owing to the absence of a printed message transfer facility (other than fax), Inmarsat-M is not type approved for use in the GMDSS.

(NB – Other Inmarsat services, including D, E, P, Aero, are available but not included in this paper. If the reader is interested in these or any other impending developments planned by INMARSAT, the author would be pleased to provide information).

INTELSAT: International Telecommunications Satellite Organisation. A consortium of telecommunications service providers who supply the satellites and control system to facilitate the provision of satellite communications for public correspondence. The transatlantic telecommunications traffic flows is INTELSAT's main area of activity.

IOR: Indian Ocean Region. A designated satellite footprint in the INMARSAT system.

ISN: Inmarsat Serial Number. A unique number assigned by an SES manufacturer to a single channel SES or to each channel of a multi channel equipment for the process of commissioning into the INMARSAT system.

ITU: International Telecommunications Union. An agency of the United Nations concerned with co-ordination of telecommunications service between sovereign states.

KDD: Kokusai Danshiu Denwa. The telecommunications authority which operates the CESs in Japan.

km: Kilometre.

LEO: Low Earth Orbit. Satellites positioned in orbital mode some 700 to 2000 km above the earth. Forty to seventy satellites would be required to provide global telecommunications coverage depending on the height of orbit.

LR: Lloyd's Register.

LRTA: Lloyd's Register Technical Association.

LSA: Life Saving Appliances. LSAs are surveyed under the Safety Equipment

certification process although some classified as "radio LSAs" are additionally required to be verified as operational during the radio survey.

Marisat: The first maritime satellite communications service which became operational in 1976 and forerunner to INMARSAT whose services it took over in 1982.

Matra Marconi Space: Company which provides the radio components in the current third generation INMARSAT satellites.

MF: Medium Frequency. Radio spectrum generally defined in the range 0.3 to 3 MHz.

MMSI: Maritime Mobile Service Identifier. Allocated by Administrations to on board GMDSS equipment which, when triggered, identifies the ship for SAR purposes.

MRGCC: Maritime Radio General Communications Certificate. The certificate of qualification for ships' radio officers issued by Administrations. For the most part this qualification was the successor, and amalgamated, the second and first class radiotelegraphy certificates for, broadly, cargo and passenger ships respectively. With the advent of GMDSS the MRGCC and its predecessor equivalents are increasingly obsolescent and should be obsolete on 1st February 1999 when GMDSS is scheduled to be fully implemented.

MSA: Marine Safety Agency. The UK Administration for shipping.

MSI: Maritime Safety Information.

MTI: Maritime Transport International. An annual shipping publication.

NASA: National Aeronautical and Space Administration. The US agency concerned with space exploration and commercial development.

NASDA: National Space Development Agency. The Japanese equivalent to NASA in the US.

NAVAREA: Navigational sea areas designated by the IHO.

NAVTEX: Term given to the MF MSI Broadcast service - cross reference by MSI above.

NCS: Network Co-ordination Station. An INMARSAT station allocated for each standard of service in each INMARSAT designated ocean region whose function is to co-ordinate the telecommunications traffic of CESs and SESs.

NIS: Norwegian International Ship-register.

NMD: Norwegian Marine Department.

NOC: Network Operations Centre. Facilitates telcommunications traffic management of the INMARSAT system. Based at the INMARSAT HQ in London.

NTC: National Telecommunications Commission. The Philippines Telecommunications Administration.

OID: Originating Identifiers. Data required during the SES commissioning procedure.

OSC: On Scene Commander. The ship which has been nominated the communications co-ordinator by the MRCC during an SAR operation.

Personal Handyphone: Mobile 'phone technology favoured by Japanese telecommunications operators – see GSM and CDMA.

POR: Pacific Ocean Region. A designated satellite footprint in the INMARSAT system.

PVT: Performance Verification Test.

QA: Quality Assurance.

QE2: Queen Elizabeth 2, UK flag cruise ship.

RCC: Rescue Co-ordination Centre.

RDF: Radio Direction Finder. Navigational aid which forms port of the statutory Safety Equipment survey.

Reg: Regulation – contained in the SOLAS.

RF: Radio Frequency. That part of the spectrum in which radio signals may be transmitted.

RO: Routing Organisation. The organisation which handles SES commissioning applications on behalf of a Flag Administration.

ROC: Restricted Operator Certificate. The certificate of qualification issued by Administrations to mariners who have demonstrated competence in the operation of a GMDSS Radio station for the GMDSS Sea Area A1 following a course of instruction and written and practical examinations.

RR:	Radio Regulations. International regulations of the ITU.
R/T:	Radiotelephony. Relates to speech radio transmission.
SAR:	Search and Rescue.
SART:	Search and Rescue Transponder. Generally referred to as radar transponders.
SCC:	Satellite Control Centre. Situated at the INMARSAT HQ in London where the monitor and control of the satellites in the INMARSAT system is carried out.
SDM:	System Definition Manual - INMARSAT technical publication for SES.
SDR:	Special Drawing Rights. A unit of exchange used by a number of telecommunications administrations to settle international accounts by converting the GF.
SD SPM:	Ship Division Survey Procedures manual. Detailed instructions provided by LR to its surveyors.
Sea Areas:	Areas designated in the GMDSS. Section 3.2 of [Ref 1] refers.
SES:	Ship Earth Station. The ship radio station which operates in the INMARSAT system.
SOLAS:	Safety of Life at Sea. Refers to the IMO Convention governing the international rules for seafarers.
Space Segment:	Term used in the satellite telecommunications services to define that element which is not earth bound. In the INMARSAT service this includes the satellites and their control systems.
TRD:	Technical Requirements Document – INMARSAT technical publication for SES.
UHF:	Ultra High Frequency. Radio spectrum generally defined in the range 300 to 3000 MHz.
UK:	United Kingdom of Great Britain and Northern Ireland.
US:	United States of America.
USA:	As US.
USCG:	United States Coast Guard.
USSR:	Union of Soviet Socialist Republics.
VHF:	Very High Frequency. Radio spectrum generally defined in the range 30 to 300 MHz.
WMO:	World Meteorology Organisation.
W/T:	Wireless Telegraphy. Refers generally to morse code transmission.

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16. Chapter III, Regulation 6, Paragraph 2.2 of SOLAS 1974 with 1988 amendments.

17. Chapter IV, Regulation 7, Paragraph 1.3 of SOLAS 1974 with 1988 amendments.

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22. RR 55 Number 3878 to 3882.

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Figures

1. Radio Transmitter of the 1920s.

2. Hand Held Satellite Transceiver projected to be available around 2000AD.

3. Inaugural INMARSAT call made to the QE2 on 1st February 1982 by the widow of Guglielmo Marconi accompanied by their daughter and the then Director General of INMARSAT, Olof Lundberg.

4. 3rd generation INMARSAT satellite. These are in the process of being deployed at the time of writing this Paper.

5. Satellite "footprints" in the INMARSAT system.

6. Satellite Dish Aerial Farm.

7. Ship Earth Station radome which encloses a directional dish aerial as used with Inmarsat-A and B systems.

8. Inmarsat-C Ship Earth Station equipment.

9. Allocated Search and Rescue regions.

10. Communication links in the Distress and Safety Services.

11. Siting of Inmarsat-A and B antennas.

12. Siting of Inmarsat-C antennas.

13. Radiation level surrounding an Inmarsat A and B antenna.

14. Radiation level surrounding an Inmarsat-C antenna.

15. NAVTEX Broadcasts available in Northern Europe.

16. Procedure for responding to a distress alert on DSC 2187.5 kHz.

17. Iridium and ICO Global hand held satellite communications systems.

Appendices

A: Record of Installation Form 2138 where an MF/HF installation is provided in compliance with Chapter IV, Regulation 10, Paragraph 2 of SOLAS 1974 with 1988 amendments.

B: Checklist Form 2137 where an MF/HF installation is provided in compliance with Chapter IV, Regulation 10, Paragraph 2 of SOLAS 1974 with 1988 amendments.

C: Record of Installation Form 2138 where an INMARSAT and MF installation is provided in compliance with Chapter IV, Regulation 10, Paragraph 1 of SOLAS 1974 with 1988 amendments.

D: Checklist Form 2137 where an INMARSAT and MF installation is provided in compliance with Chapter IV, Regulation 10, Paragraph 1 of SOLAS 1974 with 1988 amendments.

Appendix A

RECORD OF APPROVED GMDSS RADIO INSTALLATION

International Convention for the Safety of Life at Sea, 1974, as amended in 1988

Applicable to passenger ships irrespective of size and cargo ships of 300 tons gross tonnage and upwards

Name of ship	Floating
Distinctive number or letters	AIBCD
Maritime Mobile Service Identity	214681000
Port of registry	Country Harbour
Gross tonnage	19999
Date on which keel was laid	4 January 1997

This form should be kept on board and must be available for inspection by a nominated surveyor or recognised organisation at all times.

Sea areas in which the ship is certified to operate (reg IV/2): A1 ☐ A1+A2 ☐ A1+A2+A3 ☒ A1+A2+A3+A4 ☐

Methods to ensure the availability of radio facilities (reg IV/15):

- Duplication of equipment ☒
- Shore-based maintenance ☒
- At-sea maintenance capability ☐

*Sections A, B, C, H, I, J and K should be completed for all ships; also **one only** from sections D, E, F or G (dependent upon radio sea area certification required), and section L, if appropriate.*

Indicate compliance with the relevant requirements by description of the equipment (manufacturer, type identification and serial number) or appropriate response to the information requested. Mark boxes "x" to indicate satisfactory compliance.

A SOURCES OF ENERGY (reg IV/13)

A.1 **Main source of electrical power** (reg II-1/41) — voltage 220 | phase 30 | frequency 60HZ

A.2 **Emergency source of electrical power** with capacity and connection to supply the radio installations for a period of:

18 hours (cargo ships, reg II-1/43.2.3.2) **or** 36 hours (passenger ships, reg II-1/42.2.2.2) — voltage 220 | phase 30 | power 1104KW

A.3 **Reserve source of energy to supply radio installations** (reg IV/13.2)
(It is assumed that either lead-acid or nickel-alkaline secondary batteries are fitted. If a different form of power is provided, please describe it)

3.1 Location: Port Side Bridge

3.2 Capacity: 200 Ampere-hours

A.4 **Automatic charging arrangements for reserve source of energy** capable of recharging it within 10 hours (reg IV/13.6)

4.1 Manufacturer/type: Sailor N1404 | Serial number: 419521

4.2 Maximum charging current: 40 Amperes

A.5 An additional reserve source of energy may be provided to give an electrically independent supply to the "duplicated equipment"; if provided:

5.1 Location: Port Side Bridge

5.2 Capacity: 100 Ampere-hours

A.6 Automatic charging arrangements for an additional reserve source of energy, if provided:

6.1 Manufacturer/type: Sailor | Serial number: 419521

6.2 Maximum charging current: 40 Amperes

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B	RADIO INSTALLATIONS (reg IV/6)	
	Confirm that all radio installations are satisfactory in respect of the following characteristics:	
B.1	Electromagnetic compatibility	[X]
B.2	Environmental conditions	[X]
B.3	Adequate illumination of radio controls	[X]
B.4	Clear marking of radio identities	[X]
	Describe:	
B.5	Location of radio operating position	Wheelhouse
B.6	VHF radiotelephone facilities to provide navigational safety communications from the bridge	RT2048+FURNNO FM-55

C	RADIO EQUIPMENT - GENERAL (reg IV/7)			
	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
	7.1.1	**VHF radio installation** capable of transmitting and receiving:		
	7.1.1.2	Radiotelephony on channels 6+13+16	Sailor RT2048	400795
	7.1.1.1	DSC on channel 70	Sailor RM2042	423661
	7.1.1.1	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated		[X]
	7.1.2	**DSC watch receiver** on channel 70	Sailor RM2042	423661
	7.1.3	Ship's radar transponder	Serpe - 1ESM Rescuer	201-93
		(The ship's radar transponder may be one of the radar transponders required by reg III/6.2.2 (see section J) provided it is stowed in a position convenient to the navigating bridge)		
	7.1.4	**NAVTEX receiver** on 518kHz	Lokata 2	70958/4
	7.1.5	**INMARSAT EGC receiver**	Sailor H 2095	914300
		(For ships engaged exclusively on voyages in areas where an HF direct-printing telegraphy MSI service is provided, the Inmarsat EGC receiver may be replaced by an HF direct-printing telegraphy MSI receiver)		
	7.1.6	**Satellite EPIRB** (float-free)	Lokata 406 H (Y)	LM 271
		Location	Port Bridge	
		Identity (MMSI, etc.)	214681000	
	7.2	2182kHz radiotelephone distress frequency watch receiver	Delcom DC 300D	8563
	7.3	Device for generating the radiotelephone alarm signal on 2182kHz	Sailor RE 2100	407324

Every ship must also comply with the requirements for each sea area in which voyages will be undertaken; please complete ***one only*** of the following sections D, E, F or G.

D	RADIO EQUIPMENT FOR SEA AREA A1 ONLY (reg IV/8)			
	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
	8.1	Means of initiating the transmission of ship-to-shore distress alerts from the position from which the ship is normally navigated by:		
	8.1.1 **or**	VHF DSC EPIRB (see reg IV/8.3)		
	8.1.2 **or**	406 MHz satellite EPIRB		
	8.1.3 **or**	MF DSC (if service provided)		
	8.1.4 **or**	HF DSC		
	8.1.5.1 **or**	INMARSAT ship earth station		
	8.1.5.2	INMARSAT EPIRB		
	8.2	VHF general radiocommunications using radiotelephony (see reg IV/7.1.1)		

E RADIO EQUIPMENT FOR SEA AREAS A1 AND A2 ONLY (reg IV/9)

SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
9.1.1	**MF radio installation** capable of transmitting and receiving, for distress and safety purposes, on the frequencies:		
9.1.1.2	2182kHz using radiotelephony		
9.1.1.1	2187.5kHz using DSC		
9.2	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☐		
9.1.2	**Equipment capable of maintaining a continuous DSC watch on 2187.5kHz:**		
	Receiver		
	DSC unit		
9.1.3	Means of initiating the transmission of ship-to-shore distress alerts by a radio service other than MF from the position from which the ship is normally navigated by:		
9.1.3.1 **or**	406MHz satellite EPIRB		
9.1.3.2 **or**	HF DSC		
9.1.3.3.1 **or**	INMARSAT ship earth station		
9.1.3.3.2	INMARSAT EPIRB		
9.3	Transmission and reception of general radiocommunications using radiotelephony or direct-printing telegraphy by:		
9.3.1 **or**	Radio installation operating on working frequencies in the bands between 1605kHz and 4000kHz or between 4000kHz and 27500kHz		
9.3.2	INMARSAT ship earth station		

F RADIO EQUIPMENT FOR SEA AREAS A1, A2 AND A3 ONLY (reg IV/10)

Ships must comply with the requirements of ***either*** *reg IV/10.1 INMARSAT ship earth station and MF radio installation,* ***or*** *reg IV/10.2 MF/HF radio installation.*

Please therefore complete section F.1 ***or*** *F.2.*

F.1 INMARSAT ship earth station and MF radio installation (reg IV/10.1)

SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
10.1.1	**INMARSAT ship earth station** capable of:		
10.1.1.1	Transmitting and receiving distress and safety communications using direct-printing telegraphy ☐		
10.1.1.2	Initiating and receiving distress priority calls ☐		
10.1.1.3	Maintaining watch for shore-to-ship distress alerts ☐		
10.1.1.4	Transmitting and receiving general radiocommunications ☐		
10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☐		
10.1.2	**MF radio installation** capable of transmitting and receiving, for distress and safety purposes, on the frequencies:		
10.1.2.2	2182kHz using radiotelephony		
10.1.2.1	2187.5kHz using DSC		
10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☐		
10.1.3	**Equipment capable of maintaining a continuous DSC watch on 2187.5kHz:**		
	Receiver		
	DSC unit		
10.1.4	Means of initiating the transmission of ship-to-shore distress alerts from the position from which the ship is normally navigated by:		
10.1.4.1 **or**	406MHz satellite EPIRB		
10.1.4.2 **or**	HF DSC		
10.1.4.3	**Either** an **additional** INMARSAT ship earth station **or** INMARSAT EPIRB		

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F.2 MF/HF RADIO INSTALLATION (reg IV/10.2)

SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
10.2.1	**MF/HF radio installation** capable of transmitting and receiving, for distress and safety purposes, on all distress and safety frequencies in the bands between 1605kHz and 4000kHz and between 4000kHz and 27500kHz:		
10.2.1.2	Using radiotelephony	SAILOR RE 2100	407624
10.2.1.1	Using DSC	SAILOR RM 2151	427145
10.2.1.3	Using direct-printing telegraphy	SAILOR RM 2151	427145
10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated		☒
10.2.2	**Equipment capable of maintaining a continuous DSC watch on 2187.5kHz, 8414.5kHz and at least one other of all the HF DSC distress and safety frequencies:**		
	Receiver	SAILOR RM 2150	421479
	DSC unit	SAILOR RM 2150	421479
10.2.3	Means of initiating the transmission of ship-to-shore distress alerts by a radio service other than HF from the position from which the ship is normally navigated by:		
10.2.3.1 **or**	406MHz satellite EPIRB	LOKATA 406 P (X)	KP 423
10.2.3.2.1 **or**	INMARSAT ship earth station		
10.2.3.2.2	INMARSAT EPIRB		
10.2.4	Transmission and reception of general radiocommunications using radiotelephony or direct-printing telegraphy by an MF/HF radio installation operating on working frequencies in the bands between 1605kHz and 4000kHz and between 4000kHz and 27500kHz:		
	Transmitter/receiver		

G REQUIREMENTS FOR SEA AREAS A1, A2, A3 AND A4 (reg IV/11)

MF/HF radio installation ☐

Compliance is required with all parts of reg IV/10.2 (except reg IV/10.2.3.2 because reg IV/10.2.3.1 is mandatory); please refer to and complete section F.10.2.

H MAINTENANCE (reg IV/15)

For ships sailing in sea areas A3 and/or A4 a minimum of two methods of maintenance is required (reg IV/15.7); for sea areas A1 and /or A2, one method is sufficient (reg IV/15.6).

Guidance and detailed recommendations on the three methods of maintaining the availability of the functional requirements of reg IV/4 is given in the annex to IMO Assembly resolution A702(17).

Radio installations provided to satisfy the primary regulations of chapter IV are described as "basic equipment"; those provided to satisfy duplication of equipment, if used as a method of maintenance, are described as "duplicated equipment".

Irrespective of the methods used for maintenance each piece of equipment required and installed should have the manufacturer's instruction books and maintenance manuals available on board.

H.1 DUPLICATION OF EQUIPMENT (SEA AREAS A3 AND/OR A4)

Another VHF DSC radio installation and **either** an INMARSAT installation (for sea area A3) **or** an MF/HF radio installation (for sea areas A3 and/or A4) **additional** to the "basic equipment" must be provided. Please complete sections H.1.1, **either** H.1.2 **or** H.1.3, and H.1.4.

	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
H.1.1		**VHF radio installation** complying with reg IV/7.1.1 capable of transmitting and receiving:		
	7.1.1.2	Radiotelephony on channels 6+13+16	SAILOR RT 2048	400597
	7.1.1.1	DSC on channel 70	SAILOR RM 2042	423166
	7.1.1.1	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated		☒
H.1.2		**MF/HF radio installation** complying with reg IV/10.2.1 capable of transmitting and receiving, for distress and safety purposes, on all distress and safety frequencies in the bands between 1605kHz and 4000kHz and between 4000kHz and 27500kHz:		
	10.2.1.2	Using radiotelephony		
	10.2.1.1	Using DSC		
	10.2.1.3	Using direct-printing telegraphy		
	10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated		☐
	12.1.3	**Equipment complying with reg IV/10.2.2 capable of maintaining a continuous DSC watch on 2187.5kHz, 8414.5kH and at least one other of all the HF DSC distress and safety frequencies:**		
		Receiver		
		DSC unit		

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	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
H.1.3		**INMARSAT ship earth station** complying with reg IV/10.1.1 capable of:	SAILOR H2095	914300
	10.1.1.1	Transmitting and receiving distress and safety communications using direct-printing telegraphy		X
	10.1.1.2	Initiating and receiving distress priority calls		X
	10.1.1.3	Maintaining watch for shore-to-ship distress alerts		X
	10.1.1.4	Transmitting and receiving general radiocommunications		X
	10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated		X
H.1.4		**Confirm that each radio installation fitted as a "duplicated equipment" is connected to a separate antenna and is installed and ready for immediate operation from power supplies including the reserve source of energy**		X

H.2	**SHORE-BASED MAINTENANCE**		
	Arrangements	MASTER ADVISES SATISFACTORY CONTRACT	X

H.3	**AT-SEA MAINTENANCE CAPABILITY**	
3.1	Technical documentation	
3.2	Test equipment	
3.3	Spare parts	
3.4	Radio maintainer	

I CAPACITY OF RESERVE SOURCE OF ENERGY FOR RADIO INSTALLATIONS (reg IV/13.2)

The capacity of the battery must be sufficient to operate the radio installations described in reg IV/13.2 - the "basic equipment" - and/or the radio installations provided for "duplication of equipment" (if appropriate) for a minimum period of 1 hour if the emergency source of electrical power is available, and for a minimum period of 6 hours if it is not available.

For calculation of the required battery endurance the IMO recommended formula = one half of the current consumption necessary for transmission + the current consumption necessary for reception + the current consumption of any additional loads (for each radio installation). The additional loads include, as appropriate, DSC encoders/decoders, direct-printing telegraphy apparatus, and, for INMARSAT installations, all mandatory peripherals.

	Current consumption of:	Reserve source of energy (See A.3)	Additional reserve source of energy (if provided; see A.5)
I.1	**"BASIC EQUIPMENT"**		
1.1	VHF/DSC radio installation	6	6
1.2	MF radio installation		
1.3	MF/HF radio installation	15	
1.4	INMARSAT ship earth station		6
1.5	Gyro compass (if continuous heading information to the INMARSAT ship earth station is required (reg IV/13.8))		
1.6	Electrical lighting for illumination of radio controls	2	
I.2	**"DUPLICATED EQUIPMENT"**		
2.1	VHF/DSC radio installation		
2.2	MF/HF radio installation		
2.3	INMARSAT ship earth station	15	
2.4	Gyro compass (if continuous heading information to the INMARSAT ship earth station is required (reg IV/13.8))		
I.3	**OTHER EQUIPMENT PERMANENTLY CONNECTED**		
3.1			
3.2			
	Total current:	38 Amperes	12 Amperes

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I.4	ENDURANCE OF RESERVE SOURCE OF ENERGY
	To allow for the reduced capacity of a battery when discharged over a shorter period than its rated specification (usually 10 or 20 hours) a de-rating factor of 0.5 for a 1 hour discharge and 0.85 for a 6 hour discharge should be applied. The result, in hours, should exceed the IMO minimum requirement.
4.1	Reserve source of energy (Section A.3) AH capacity of battery x de-rating / total current = 200 x 0.5 / 38 = 2.6 hours
4.2	Additional reserve source of energy (if provided; Section A.5) AH capacity of battery x de-rating / total current = 100 x 0.5 / 12 = 4.2 hours

J RADIO LIFE-SAVING APPLIANCES (reg III/6.2)

SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
6.2.1	**Two-way VHF radiotelephone apparatus**	FURUNO FM - 55	2435 - 1697
		FURUNO FM - 55	- 1698
		FURUNO FM - 55	- 1698
	Location	WHEELHOUSE	
6.2.2	**Radar transponders**	SERPE IESM RESCUER	204 - 93
		SERPE IESM RESCUER	205 - 93
	Location	PORT & STARBOARD WHEELHOUSE	

K	PERFORMANCE STANDARDS (reg IV/14)	
K.1	Any INMARSAT ship earth station provided to satisfy reg IV/10.1.1 for "basic equipment" or "duplicated equipment" is installed fully in compliance with the relevant IMO performance standard and associated INMARSAT design and installation guidelines	X
K.2	All equipment fitted conforms to performance standards adopted by IMO and with type approval specifications accepted by the flag state	X

L	ADDITIONAL RADIOCOMMUNICATIONS EQUIPMENT
	(additional to, and not considered for, SOLAS requirements)
L.1	
L.2	

Surveyed by:	
Radio Surveyor	B Murphy
Port	SEEPORT WEST
Date	10.03.97

Accepted by:	
LR Surveyor	L. Smith.
Port	SEEPORT
Date	10.03.97

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Appendix B

SURVEY CHECK LIST - GMDSS - SAFETY RADIO

International Convention for the Safety of Life at Sea, 1974, as amended in 1988

Survey requirements for passenger ships irrespective of size and cargo ships of 300 tons gross tonnage and upwards

Name of ship	FLOATING
Distinctive number or letters	AIBCD
Maritime Mobile Service Identity	21468100
Port of registry	COUNTRY HARBOUR
Gross tonnage	19999
Date on which keel was laid	4 JANUARY 1997

Complete all relevant sections; give information, dates or measurements, as appropriate. Mark boxes "x" to indicate satisfactory inspection. Dates should be given in the format mm/yy (month/year; eg May 1997 = 05/97).

A satisfactory operational status means that all major operating facilities and requirements of the equipment or unit have been tested and found to function in accordance with the relevant SOLAS regulations and associated IMO performance standards.

The "Record of Approved GMDSS Radio Installation", form 2138, reference SEE 400513 (port/report number) dated 03/97 (mm/yy):

is confirmed available on board ☐ was not found on board ☐ is attached with this checklist ☒

Sea areas in which the ship is certified to operate: A1 ☐ A1+A2 ☐ A1+A2+A3 ☒ A1+A2+A3+A4 ☐

Methods to ensure the availability of radio facilities:

- Duplication of equipment ☒
- Shore-based maintenance ☒
- At-sea maintenance capability ☐

AA	SOURCES OF ENERGY (reg IV/13)		
	Item	Details	Operational status
1.0	Main source of electrical power		☒
2.0	Emergency source of electrical power (if provided)		☒
3.0	Reserve source of energy to supply radio installations (radio battery)		☒
3.1	Battery charger; charging current	15 Amperes	
3.2	Date when battery capacity was last verified (mm/yy)	05/96	
3.3	Other relevant data (for example: specific gravity, date of battery manufacture)	1.260	
4.0	An additional reserve source of energy (additional radio battery) if provided		☒
4.1	Battery charger; charging current	10 Amperes	
4.2	Date when battery capacity was last verified (mm/yy)	06/96	
4.3	Other relevant data (for example: specific gravity, date of battery manufacture)	1.360	

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BB	RADIO INSTALLATION - RADIOCOMMUNICATIONS (CHAPTER IV) Form R - Section 2	
1.0	**Primary systems ("Basic equipment" ONLY)**	Operational status
1.1	VHF radio installation:	
1.1.1	DSC encoder/decoder	X
1.1.2	DSC watch receiver	X
1.1.3	Radiotelephony	X
1.2	MF radio installation:	
1.2.1	DSC encoder/decoder	
1.2.2	DSC watch receiver	
1.2.3	Radiotelephony	
1.3	MF/HF radio installation:	
1.3.1	DSC encoder/decoder	X
1.3.2	DSC watch receiver	X
1.3.3	Radiotelephony	X
1.3.4	Direct-printing telegraphy	X
1.4	INMARSAT ship earth station	
2.0	Secondary means of alerting:	
	Designated equipment (specify) Satellite EPIRB	X
3.0	Facilities for reception of MSI:	
3.1	NAVTEX receiver	X
3.2	EGC receiver	X
3.3	HF direct-printing radiotelegraph receiver (if ship exempted from Inmarsat EGC receiver)	
4.0	Satellite EPIRB (float-free):	
4.1 or	COSPAS-SARSAT	X
4.2	INMARSAT	
	battery expiry date (mm/yy) 07/02	
	hydrostatic release expiry date (mm/yy) 06/01	
5.0	VHF EPIRB	
6.0	Ship's radar transponder	See section DD 1.2
7.0	Radiotelephone distress frequency watch receiver on 2182kHz	X
8.0	Device for generating the radiotelephone alarm signal on 2182kHz	X

CC	METHODS USED TO ENSURE AVAILABILITY OF RADIO FACILITIES (reg IV/15) Form R - Section 3	
1.0	Duplication of equipment:	Operational status
1.1	VHF DSC installation as "duplicated equipment"	X
1.2 or	INMARSAT ship earth station as "duplicated equipment"	X
1.3	MF/HF radio installation as "duplicated equipment"	
2.0	Shore-based maintenance:	
	Arrangements acceptable to flag state	X
3.0	At-sea maintenance capability:	
	Spares/documentation/test equipment	
	Suitably qualified radio maintainer	

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DD	RADIO INSTALLATIONS - LIFE-SAVING APPLIANCES (reg III/6.2) Form E - Section 2			
	Item			Operational status
1.1	Two-way VHF radiotelephone apparatus			X
	primary battery expiry date (mm/yy)	(a) 12/01	(b) 12/01	(c) 12/01
	and/or rechargeable batteries and battery charger			X
1.2	Radar transponders			X
	battery expiry date (mm/yy)	(a) 10/01	(b) 10/01	

EE	WATCHES ("Basic equipment") (reg IV/12)		
1.0	On VHF DSC channel 70	(all sea areas)	X
2.0	On MF DSC 2187.5kHz	(sea area A2 only)	
3.0 or	On MF DSC 2187.5kHz and an INMARSAT ship earth station (reg IV/10.1)	(sea area A3)	
4.0	On MF/HF DSC 2187.5kHz, 8414.5kHz and at least one other HF DSC distress and safety frequency (reg IV/10.2)	(sea area A3 and/or A4)	X
5.0	On VHF radiotelephone channel 16	(all sea areas)	X
6.0	On the radiotelephone distress frequency 2182kHz	(all sea areas)	X
7.0	Aural alarms and visual indications for reception of distress alerts	(all sea areas)	X

FF	PERSONNEL FOR OPERATING THE RADIO INSTALLATIONS (reg IV/16)			
1.0	Name	J. Spark	Name	
	Certificate	GMDSS GOC - 2468/95	Certificate	
	Administration	Country	Administration	
2.0	ITU publications required by Radio Regulations Appendix 11 section VA			X
3.0	Radio record (logbook) is available and properly kept (reg IV/17)			X

GG	CHANGES TO "RECORD OF APPROVED GMDSS RADIO INSTALLATION", form 2138:
1.0	
2.0	
3.0	

HH	DEFICIENCIES (See reg IV/15.8)
1.0	
2.0	
3.0	
4.0	

This is to certify that:

(a) a safety radio survey has been carried out in accordance with the relevant regulations of the Convention and as described above;

(b) deficiencies, if any, are described in section HH;

(c) all the functional requirements of reg IV/4 appropriate to the sea area or areas specified are provided and are operational.

If any one of the functional requirements of reg IV/4 is not available (excepting reg IV/4.1.8), whether using "basic" or "duplicated" equipment, a safety radio certificate should not be issued.

Surveyed by:	
Radio Surveyor	R. Murphy
Port	Seeport West
Date	10.03.97

Accepted by:	
LR Surveyor	L. Smith
Port	Seeport
Date	12.03.97

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Appendix C

RECORD OF APPROVED GMDSS RADIO INSTALLATION

International Convention for the Safety of Life at Sea, 1974, as amended in 1988

Applicable to passenger ships irrespective of size and cargo ships of 300 tons gross tonnage and upwards

Name of ship	FLOATING
Distinctive number or letters	AIBCD
Maritime Mobile Service Identity	214681000
Port of registry	Country Harbour
Gross tonnage	19999
Date on which keel was laid	4 January 1997

This form should be kept on board and must be available for inspection by a nominated surveyor or recognised organisation at all times.

Sea areas in which the ship is certified to operate (reg IV/2): A1 ☐ A1+A2 ☐ A1+A2+A3 ☒ A1+A2+A3+A4 ☐

Methods to ensure the availability of radio facilities (reg IV/15):

- Duplication of equipment ☒
- Shore-based maintenance ☒
- At-sea maintenance capability ☐

*Sections A, B, C, H, I, J and K should be completed for all ships; also **one only** from sections D, E, F or G (dependent upon radio sea area certification required), and section L, if appropriate.*

Indicate compliance with the relevant requirements by description of the equipment (manufacturer, type identification and serial number) or appropriate response to the information requested. Mark boxes "x" to indicate satisfactory compliance.

A SOURCES OF ENERGY (reg IV/13)

A.1 **Main source of electrical power** (reg II-1/41) — voltage 220 | phase 30 | frequency 60HZ

A.2 **Emergency source of electrical power** with capacity and connection to supply the radio installations for a period of:

18 hours (cargo ships, reg II-1/43.2.3.2) **or** 36 hours (passenger ships, reg II-1/42.2.2.2) — voltage 220 | phase 30 | power 1104KW

A.3 **Reserve source of energy to supply radio installations** (reg IV/13.2)
(It is assumed that either lead-acid or nickel-alkaline secondary batteries are fitted. If a different form of power is provided, please describe it)

3.1 Location: PORT SIDE BRIDGE

3.2 Capacity: 220 Ampere-hours

A.4 **Automatic charging arrangements for reserve source of energy** capable of recharging it within 10 hours (reg IV/13.6)

4.1 Manufacturer/type: SAILOR N1404 | Serial number: 419521

4.2 Maximum charging current: 40 Amperes

A.5 An additional reserve source of energy may be provided to give an electrically independent supply to the "duplicated equipment"; if provided:

5.1 Location: PORT SIDE BRIDGE

5.2 Capacity: 100 Ampere-hours

A.6 Automatic charging arrangements for an additional reserve source of energy, if provided:

6.1 Manufacturer/type: SAILOR | Serial number: 419521

6.2 Maximum charging current: 40 Amperes

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B	RADIO INSTALLATIONS (reg IV/6)	
	Confirm that all radio installations are satisfactory in respect of the following characteristics:	
B.1	Electromagnetic compatibility	X
B.2	Environmental conditions	X
B.3	Adequate illumination of radio controls	X
B.4	Clear marking of radio identities	X
	Describe:	
B.5	Location of radio operating position	WHEELHOUSE
B.6	VHF radiotelephone facilities to provide navigational safety communications from the bridge	RT 2048 + FURUNO FM-55

C	RADIO EQUIPMENT - GENERAL (reg IV/7)			
	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
	7.1.1	**VHF radio installation** capable of transmitting and receiving:		
	7.1.1.2	Radiotelephony on channels 6+13+16	SAILOR RT 2048	400795
	7.1.1.1	DSC on channel 70	SAILOR RM 2042	423661
	7.1.1.1	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated		X
	7.1.2	**DSC watch receiver** on channel 70	SAILOR RM 2042	423661
	7.1.3	Ship's radar transponder	SERPE - IESM RESCUER	201-93
		(The ship's radar transponder may be one of the radar transponders required by reg III/6.2.2 (see section J) provided it is stowed in a position convenient to the navigating bridge)		
	7.1.4	**NAVTEX receiver** on 518kHz	LOKATA 2	70958/4
	7.1.5	**INMARSAT EGC receiver**	SAILOR H 2095	914300
		(For ships engaged exclusively on voyages in areas where an HF direct-printing telegraphy MSI service is provided, the Inmarsat EGC receiver may be replaced by an HF direct-printing telegraphy MSI receiver)		
	7.1.6	**Satellite EPIRB** (float-free)	LOKATA 406 H (Y)	LM 271
		Location	Port Bridge	
		Identity (MMSI, etc.)	214681000	
	7.2	2182kHz radiotelephone distress frequency watch receiver	DELCOM DC 300D	8563
	7.3	Device for generating the radiotelephone alarm signal on 2182kHz	SAILOR RE 2100	407324

Every ship must also comply with the requirements for each sea area in which voyages will be undertaken; please complete ***one only*** of the following sections D, E, F or G.

D	RADIO EQUIPMENT FOR SEA AREA A1 ONLY (reg IV/8)			
	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
	8.1	Means of initiating the transmission of ship-to-shore distress alerts from the position from which the ship is normally navigated by:		
	8.1.1 **or**	VHF DSC EPIRB (see reg IV/8.3)		
	8.1.2 **or**	406 MHz satellite EPIRB		
	8.1.3 **or**	MF DSC (if service provided)		
	8.1.4 **or**	HF DSC		
	8.1.5.1 **or**	INMARSAT ship earth station		
	8.1.5.2	INMARSAT EPIRB		
	8.2	VHF general radiocommunications using radiotelephony (see reg IV/7.1.1)		

E RADIO EQUIPMENT FOR SEA AREAS A1 AND A2 ONLY (reg IV/9)

SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
9.1.1	**MF radio installation** capable of transmitting and receiving, for distress and safety purposes, on the frequencies:		
9.1.1.2	2182kHz using radiotelephony		
9.1.1.1	2187.5kHz using DSC		
9.2	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☐		
9.1.2	**Equipment capable of maintaining a continuous DSC watch on 2187.5kHz:**		
	Receiver		
	DSC unit		
9.1.3	Means of initiating the transmission of ship-to-shore distress alerts by a radio service other than MF from the position from which the ship is normally navigated by:		
9.1.3.1 or	406MHz satellite EPIRB		
9.1.3.2 or	HF DSC		
9.1.3.3.1 or	INMARSAT ship earth station		
9.1.3.3.2	INMARSAT EPIRB		
9.3	Transmission and reception of general radiocommunications using radiotelephony or direct-printing telegraphy by:		
9.3.1 or	Radio installation operating on working frequencies in the bands between 1605kHz and 4000kHz or between 4000kHz and 27500kHz		
9.3.2	INMARSAT ship earth station		

F RADIO EQUIPMENT FOR SEA AREAS A1, A2 AND A3 ONLY (reg IV/10)

Ships must comply with the requirements of ***either*** *reg IV/10.1 INMARSAT ship earth station and MF radio installation,* ***or*** *reg IV/10.2 MF/HF radio installation.*

Please therefore complete section F.1 ***or*** *F.2.*

F.1 INMARSAT ship earth station and MF radio installation (reg IV/10.1)

SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
10.1.1	**INMARSAT ship earth station** capable of:	Sailor H2095	914200
10.1.1.1	Transmitting and receiving distress and safety communications using direct-printing telegraphy ☒		
10.1.1.2	Initiating and receiving distress priority calls ☒		
10.1.1.3	Maintaining watch for shore-to-ship distress alerts ☒		
10.1.1.4	Transmitting and receiving general radiocommunications ☒		
10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☒		
10.1.2	**MF radio installation** capable of transmitting and receiving, for distress and safety purposes, on the frequencies:		
10.1.2.2	2182kHz using radiotelephony	Sailor T2130	421148
10.1.2.1	2187.5kHz using DSC	Sailor RM2151	427145
10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☒		
10.1.3	**Equipment capable of maintaining a continuous DSC watch on 2187.5kHz:**		
	Receiver	Sailor RM 2150	421479
	DSC unit	Sailor RM 2150	421479
10.1.4	Means of initiating the transmission of ship-to-shore distress alerts from the position from which the ship is normally navigated by:		
10.1.4.1 or	406MHz satellite EPIRB	Lokata 406 (P)	KP423
10.1.4.2 or	HF DSC		
10.1.4.3	**Either** an **additional** INMARSAT ship earth station **or** INMARSAT EPIRB		

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F.2 MF/HF RADIO INSTALLATION (reg IV/10.2)

SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
10.2.1	**MF/HF radio installation** capable of transmitting and receiving, for distress and safety purposes, on all distress and safety frequencies in the bands between 1605kHz and 4000kHz and between 4000kHz and 27500kHz:		
10.2.1.2	Using radiotelephony		
10.2.1.1	Using DSC		
10.2.1.3	Using direct-printing telegraphy		
10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☐		
10.2.2	**Equipment capable of maintaining a continuous DSC watch on 2187.5kHz, 8414.5kHz and at least one other of all the HF DSC distress and safety frequencies:**		
	Receiver		
	DSC unit		
10.2.3	Means of initiating the transmission of ship-to-shore distress alerts by a radio service other than HF from the position from which the ship is normally navigated by:		
10.2.3.1 **or**	406MHz satellite EPIRB		
10.2.3.2.1 **or**	INMARSAT ship earth station		
10.2.3.2.2	INMARSAT EPIRB		
10.2.4	Transmission and reception of general radiocommunications using radiotelephony or direct-printing telegraphy by an MF/HF radio installation operating on working frequencies in the bands between 1605kHz and 4000kHz and between 4000kHz and 27500kHz:		
	Transmitter/receiver		

G REQUIREMENTS FOR SEA AREAS A1, A2, A3 AND A4 (reg IV/11)

MF/HF radio installation ☐

Compliance is required with all parts of reg IV/10.2 (except reg IV/10.2.3.2 because reg IV/10.2.3.1 is mandatory); please refer to and complete section F.10.2.

H MAINTENANCE (reg IV/15)

For ships sailing in sea areas A3 and/or A4 a minimum of two methods of maintenance is required (reg IV/15.7); for sea areas A1 and /or A2, one method is sufficient (reg IV/15.6).

Guidance and detailed recommendations on the three methods of maintaining the availability of the functional requirements of reg IV/4 is given in the annex to IMO Assembly resolution A702(17).

Radio installations provided to satisfy the primary regulations of chapter IV are described as "basic equipment"; those provided to satisfy duplication of equipment, if used as a method of maintenance, are described as "duplicated equipment".

Irrespective of the methods used for maintenance each piece of equipment required and installed should have the manufacturer's instruction books and maintenance manuals available on board.

H.1 DUPLICATION OF EQUIPMENT (SEA AREAS A3 AND/OR A4)

Another VHF DSC radio installation and **either** an INMARSAT installation (for sea area A3) **or** an MF/HF radio installation (for sea areas A3 and/or A4) **additional** to the "basic equipment" must be provided. Please complete sections H.1.1, **either** H.1.2 **or** H.1.3, and H.1.4.

	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
H.1.1		**VHF radio installation** complying with reg IV/7.1.1 capable of transmitting and receiving:		
	7.1.1.2	Radiotelephony on channels 6+13+16	Sailor RT 2048	400597
	7.1.1.1	DSC on channel 70	Sailor RM 2042	423166
	7.1.1.1	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☒		
H.1.2		**MF/HF radio installation** complying with reg IV/10.2.1 capable of transmitting and receiving, for distress and safety purposes, on all distress and safety frequencies in the bands between 1605kHz and 4000kHz and between 4000kHz and 27500kHz:		
	10.2.1.2	Using radiotelephony		
	10.2.1.1	Using DSC		
	10.2.1.3	Using direct-printing telegraphy		
	10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated ☐		
	12.1.3	**Equipment complying with reg IV/10.2.2 capable of maintaining a continuous DSC watch on 2187.5kHz, 8414.5kH and at least one other of all the HF DSC distress and safety frequencies:**		
		Receiver		
		DSC unit		

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	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
H.1.3		**INMARSAT ship earth station** complying with reg IV/10.1.1 capable of:	Sailor H2095	914300
	10.1.1.1	Transmitting and receiving distress and safety communications using direct-printing telegraphy		X
	10.1.1.2	Initiating and receiving distress priority calls		X
	10.1.1.3	Maintaining watch for shore-to-ship distress alerts		X
	10.1.1.4	Transmitting and receiving general radiocommunications		X
	10.3	Means of initiating the transmission of distress alerts from the position from which the ship is normally navigated		X
H.1.4		**Confirm that each radio installation fitted as a "duplicated equipment" is connected to a separate antenna and is installed and ready for immediate operation from power supplies including the reserve source of energy**		X

H.2	**SHORE-BASED MAINTENANCE**	
	Arrangements	Master Advises Satisfactory Contract X

H.3	**AT-SEA MAINTENANCE CAPABILITY**	
3.1	Technical documentation	
3.2	Test equipment	
3.3	Spare parts	
3.4	Radio maintainer	

I	**CAPACITY OF RESERVE SOURCE OF ENERGY FOR RADIO INSTALLATIONS (reg IV/13.2)**		
	The capacity of the battery must be sufficient to operate the radio installations described in reg IV/13.2 - the "basic equipment" - and/or the radio installations provided for "duplication of equipment" (if appropriate) for a minimum period of 1 hour if the emergency source of electrical power is available, and for a minimum period of 6 hours if it is not available.		
	For calculation of the required battery endurance the IMO recommended formula = one half of the current consumption necessary for transmission + the current consumption necessary for reception + the current consumption of any additional loads (for each radio installation). The additional loads include, as appropriate, DSC encoders/decoders, direct-printing telegraphy apparatus, and, for INMARSAT installations, all mandatory peripherals.		
	Current consumption of:	Reserve source of energy (See A.3)	Additional reserve source of energy (if provided; see A.5)
I.1	**"BASIC EQUIPMENT"**		
1.1	VHF/DSC radio installation	6	6
1.2	MF radio installation		
1.3	MF/HF radio installation	15	
1.4	INMARSAT ship earth station		6
1.5	Gyro compass (if continuous heading information to the INMARSAT ship earth station is required (reg IV/13.8))		
1.6	Electrical lighting for illumination of radio controls	2	
I.2	**"DUPLICATED EQUIPMENT"**		
2.1	VHF/DSC radio installation		
2.2	MF/HF radio installation		
2.3	INMARSAT ship earth station	15	
2.4	Gyro compass (if continuous heading information to the INMARSAT ship earth station is required (reg IV/13.8))		
I.3	**OTHER EQUIPMENT PERMANENTLY CONNECTED**		
3.1			
3.2			
	Total current:	38 Amperes	12 Amperes

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I.4	ENDURANCE OF RESERVE SOURCE OF ENERGY
	To allow for the reduced capacity of a battery when discharged over a shorter period than its rated specification (usually 10 or 20 hours) a de-rating factor of 0.5 for a 1 hour discharge and 0.85 for a 6 hour discharge should be applied. The result, in hours, should exceed the IMO minimum requirement.
4.1	Reserve source of energy (Section A.3) AH capacity of battery x de-rating / total current = 220 x 0.5 / 38 = 2.9 hours
4.2	Additional reserve source of energy (if provided; Section A.5) AH capacity of battery x de-rating / total current = 100 x 0.5 / 12 = 4.2 hours

J	RADIO LIFE-SAVING APPLIANCES (reg III/6.2)			
	SOLAS REG	REQUIREMENT	DESCRIPTION OF EQUIPMENT	SERIAL NUMBER
	6.2.1	**Two-way VHF radiotelephone apparatus**	Furuno FM-55	2435 - 1697
			Furuno FM-55	- 1698
			Furuno FM-55	- 1698
		Location	Wheel House	
	6.2.2	**Radar transponders**	Serpe IESM Rescuer	204 - 93
			Serpe IESM Rescuer	205 - 93
		Location	Port & Starboard Wheel House	

K	PERFORMANCE STANDARDS (reg IV/14)	
K.1	Any INMARSAT ship earth station provided to satisfy reg IV/10.1.1 for "basic equipment" or "duplicated equipment" is installed fully in compliance with the relevant IMO performance standard and associated INMARSAT design and installation guidelines	X
K.2	All equipment fitted conforms to performance standards adopted by IMO and with type approval specifications accepted by the flag state	X

L	ADDITIONAL RADIOCOMMUNICATIONS EQUIPMENT
	(additional to, and not considered for, SOLAS requirements)
L.1	
L.2	

Surveyed by:	
Radio Surveyor	B. Murphy
Port	Seeport West
Date	10.03.97

Accepted by:	
LR Surveyor	L. Smith.
Port	Seeport
Date	10.03.97

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Appendix D

SURVEY CHECK LIST - GMDSS - SAFETY RADIO

International Convention for the Safety of Life at Sea, 1974, as amended in 1988

Survey requirements for passenger ships irrespective of size and cargo ships of 300 tons gross tonnage and upwards

Name of ship	FLOATING
Distinctive number or letters	AIBCD
Maritime Mobile Service Identity	21468100
Port of registry	COUNTRY HARBOUR
Gross tonnage	19999
Date on which keel was laid	4 JANUARY 1997

Complete all relevant sections; give information, dates or measurements, as appropriate. Mark boxes "x" to indicate satisfactory inspection. Dates should be given in the format mm/yy (month/year; eg May 1997 = 05/97).

A satisfactory operational status means that all major operating facilities and requirements of the equipment or unit have been tested and found to function in accordance with the relevant SOLAS regulations and associated IMO performance standards.

The "Record of Approved GMDSS Radio Installation", form 2138, reference SEE 400513 (port/report number) dated 03/97 (mm/yy):

is confirmed available on board ☐ was not found on board ☐ is attached with this checklist ☒

Sea areas in which the ship is certified to operate: A1 ☐ A1+A2 ☐ A1+A2+A3 ☒ A1+A2+A3+A4 ☐

Methods to ensure the availability of radio facilities:

- Duplication of equipment ☒
- Shore-based maintenance ☒
- At-sea maintenance capability ☐

AA	SOURCES OF ENERGY (reg IV/13)		
	Item	Details	Operational status
1.0	Main source of electrical power		☒
2.0	Emergency source of electrical power (if provided)		☒
3.0	Reserve source of energy to supply radio installations (radio battery)		☒
3.1	Battery charger; charging current	15 Amperes	
3.2	Date when battery capacity was last verified (mm/yy)	05/96	
3.3	Other relevant data (for example: specific gravity, date of battery manufacture)	1.260	
4.0	An additional reserve source of energy (additional radio battery) if provided		☒
4.1	Battery charger; charging current	10 Amperes	
4.2	Date when battery capacity was last verified (mm/yy)	06/96	
4.3	Other relevant data (for example: specific gravity, date of battery manufacture)	1.360	

LR/IMO number	Port/Report number	Page
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FORM 2137 (10/95) LLOYD'S REGISTER OF SHIPPING 71 FENCHURCH STREET, LONDON EC3M 4BS

BB	RADIO INSTALLATION - RADIOCOMMUNICATIONS (CHAPTER IV) Form R - Section 2	
1.0	**Primary systems ("Basic equipment" ONLY)**	Operational status
1.1	VHF radio installation:	
1.1.1	DSC encoder/decoder	X
1.1.2	DSC watch receiver	X
1.1.3	Radiotelephony	X
1.2	MF radio installation:	
1.2.1	DSC encoder/decoder	X
1.2.2	DSC watch receiver	X
1.2.3	Radiotelephony	X
1.3	MF/HF radio installation:	
1.3.1	DSC encoder/decoder	
1.3.2	DSC watch receiver	
1.3.3	Radiotelephony	
1.3.4	Direct-printing telegraphy	
1.4	INMARSAT ship earth station	X
2.0	Secondary means of alerting:	
	Designated equipment (specify) Satellite EPIRB	X
3.0	Facilities for reception of MSI:	
3.1	NAVTEX receiver	X
3.2	EGC receiver	X
3.3	HF direct-printing radiotelegraph receiver (if ship exempted from Inmarsat EGC receiver)	
4.0	Satellite EPIRB (float-free):	
4.1 or	COSPAS-SARSAT	X
4.2	INMARSAT	
	battery expiry date (mm/yy) 06/01	
	hydrostatic release expiry date (mm/yy) 07/02	
5.0	VHF EPIRB	
6.0	Ship's radar transponder	See section DD 1.2
7.0	Radiotelephone distress frequency watch receiver on 2182kHz	X
8.0	Device for generating the radiotelephone alarm signal on 2182kHz	X

CC	METHODS USED TO ENSURE AVAILABILITY OF RADIO FACILITIES (reg IV/15) Form R - Section 3	
1.0	Duplication of equipment:	Operational status
1.1	VHF DSC installation as "duplicated equipment"	X
1.2 or	INMARSAT ship earth station as "duplicated equipment"	X
1.3	MF/HF radio installation as "duplicated equipment"	
2.0	Shore-based maintenance:	
	Arrangements acceptable to flag state	X
3.0	At-sea maintenance capability:	
	Spares/documentation/test equipment	
	Suitably qualified radio maintainer	

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FORM 2137 (10/95) LLOYD'S REGISTER OF SHIPPING 71 FENCHURCH STREET, LONDON EC3M 4BS

DD	RADIO INSTALLATIONS - LIFE-SAVING APPLIANCES (reg III/6.2) Form E - Section 2		
	Item		Operational status
1.1	Two-way VHF radiotelephone apparatus		[X]
	primary battery expiry date (mm/yy) (a) 12/02 (b) 12/02 (c) 12/02		
	and/or rechargeable batteries and battery charger		[X]
1.2	Radar transponders		[X]
	battery expiry date (mm/yy) (a) 10/01 (b) 10/01		

EE	WATCHES ("Basic equipment") (reg IV/12)		
1.0	On VHF DSC channel 70	(all sea areas)	[X]
2.0	On MF DSC 2187.5kHz	(sea area A2 only)	[ ]
3.0 or 4.0	On MF DSC 2187.5kHz and an INMARSAT ship earth station (reg IV/10.1)	(sea area A3)	[X]
	On MF/HF DSC 2187.5kHz, 8414.5kHz and at least one other HF DSC distress and safety frequency (reg IV/10.2)	(sea area A3 and/or A4)	[ ]
5.0	On VHF radiotelephone channel 16	(all sea areas)	[X]
6.0	On the radiotelephone distress frequency 2182kHz	(all sea areas)	[X]
7.0	Aural alarms and visual indications for reception of distress alerts	(all sea areas)	[X]

FF	PERSONNEL FOR OPERATING THE RADIO INSTALLATIONS (reg IV/16)			
1.0	Name	J. Spark	Name	
	Certificate	GMDSS GOC - 2468/95	Certificate	
	Administration	Country	Administration	
2.0	ITU publications required by Radio Regulations Appendix 11 section VA			[X]
3.0	Radio record (logbook) is available and properly kept (reg IV/17)			[X]

GG	CHANGES TO "RECORD OF APPROVED GMDSS RADIO INSTALLATION", form 2138:
1.0	
2.0	
3.0	

HH	DEFICIENCIES (See reg IV/15.8)
1.0	
2.0	
3.0	
4.0	

This is to certify that:

(a) a safety radio survey has been carried out in accordance with the relevant regulations of the Convention and as described above;

(b) deficiencies, if any, are described in section HH;

(c) all the functional requirements of reg IV/4 appropriate to the sea area or areas specified are provided and are operational.

If any one of the functional requirements of reg IV/4 is not available (excepting reg IV/4.1.8), whether using "basic" or "duplicated" equipment, a safety radio certificate should not be issued.

Surveyed by:	
Radio Surveyor	R. Murphy
Port	Seeport West
Date	10.03.97

Accepted by:	
LR Surveyor	L. Smith.
Port	Seeport
Date	12.03.97

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FORM 2137 (10/95) LLOYD'S REGISTER OF SHIPPING 71 FENCHURCH STREET, LONDON EC3M 4BS

LR *Technical Association*

Experience with Verification Schemes under new UK Offshore Regulations

by P. C. Campbell and H. J. Sewell

Lloyd's Register

Paper No **6**
Session 1996–1997

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Written contributions to the discussion of this paper are invited from members of the Lloyd's Register Technical Association. To ensure inclusion in the discussion paper, the contributions should be received by the Hon. Secretary in London not later than 31st June 1997.

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Enquiries should be addressed to Lloyd's Register of Shipping, 71 Fenchurch Street, London EC3M 4BS, England.

HONORARY SECRETARY, LR TECHNICAL ASSOCIATION
A. J. Williamson
71 Fenchurch Street, London EC3M 4BS

JCA

LR *Technical Association*

Discussion on the Paper

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Hon. Sec. A. J. Williamson
71 Fenchurch Street, London, EC3M 4BS

Experience with Verification Schemes under new UK Offshore Regulations

by P. C. Campbell and H. J. Sewell

DISCUSSION

From: Mr W. H. Chan

Thank you for a most useful Paper. It was noticed from one of the slides during your presentation that design appraisal is identified as a first-level activity to be performed by the Independent Verification Body (IVB). At a higher level, aspects such as reliability, availability, survivability etc. are also to be verified. These aspects are closely related to numerous factors, such as:

(i) what is expected to happen in the event of an incident,
(ii) degree and frequency of plant maintenance,
(iii) the training and competence of operators.

In other words, more than can be ascertained from a drawing. Can I ask the Authors to confirm that these aspects are beyond the usual scope of design appraisal and that, without specialist training on these safety issues, the design appraisal Surveyors would not be in a position to implement appraisal of these matters. Furthermore, does it not follow, that the role of the Surveyor would be constrained to checking for the provision of duplication/redundancy of equipment already required by existing codes or industry practices?

To: Mr W. H. Chan

With respect to Mr Chan's first point, our view is that the issues to be addressed by LR's design examination should remain broadly similar because the safety criticality of the structure and plant has not in principle changed, but that, with Independent Competent Person (ICP) services, we are obliged to formalise our checking scope and methods to provide visibility and audibility within the dutyholders scheme of verification.

Although the terms that are used in the context of verification are new, e.g., "safety critical" and "performance standards", this is not considered to fundamentally change our remit which (as within classification) remains focused on those issues which have a bearing on the safe operation of structures and plant facility. To enhance this formalised approach it is becoming standard practice to create detailed work instructions to act as a formal checklist of issues to be addressed. This approach has the benefit of ensuring that a consistent level of checking is performed across LR, irrespective of individual preferences. This is important since LR as an IVB, is no longer verifying regulation compliance, rather we are contributing to an auditable scheme of verification which forms a part of dutyholders' responsibilities within the Safety Case Regulations.

This also has the advantage of ensuring that the limits of our verification service are clearly defined, which helps avoid misunderstanding of the extent of our examination, and thereby our liabilities.

However, notwithstanding the above, it would appear that the process of formalisation and documentation of issues to be checked by individual discipline groups (within Detailed Work Instructions) has highlighted a number of safety issues which may not previously have been as widely appreciated to merit attention at the design review stage.

On Mr Chan's second point, our understanding is that the constraint to which he refers should be applied to ensure that the design examination to be undertaken by the Surveyor is limited to issues (performance requirements) which have a direct bearing on safety.

The numerous safety related factors, such as the three to which Mr Chan refers, are required to be addressed by the dutyholder in the Safety Management System within the Safety Case, but are not issues for consideration as part of initial verification. Clearly, however, the degree/frequency of plant maintenance will have a bearing on the likelihood of the plant continuing to operate in a suitable condition, and thereby influence the routines of examination and likely findings of the verifier during the plant's service life.

From: Mr R. Potthurst

I would first like to offer my congratulations to the Authors for a very interesting and topical Paper. The Paper provides a useful reference document regarding application of the new UK regulations. Verification work will occupy a prominent position in LR's future UK offshore business and it is certain that other national authorities will develop similar regulations. Could the Authors give their views on the possibility of conflicting requirements at interfaces between hull systems designed using Class Rules, and topside systems designed using international codes and standards?

To: Mr R. Potthurst

The possibility of conflicting requirements at interfaces between hull systems designed to comply with the Class Rules and topside systems designed to meet international codes and standards may continue under the new verification regime. However, unlike the conflicts thrown up by apparent contradictory prescriptive requirements under certification and classification, the new regulations do not bind designers to any particular prescriptive requirement, rather they enforce the establishment of performance requirements to manage a hazard. Thus, the use of Class and/or international codes and standards may be assessed on a case by case basis to evaluate the contribution derived from their compliance in meeting the performance requirement.

Dutyholders are therefore free to choose a performance standard which addresses the hazards identified in the Safety Case. Class Rules can then be treated as any other internationally recognised code or standard, which may be used to form the basis of a performance standard. It is therefore a matter of the dutyholder having the option to elect to apply Class Rules or any other international standard, providing the standard delivers appropriate performance. It is also important that the interfaces which may exist by such election are clear for the benefit of designers, builders and verifiers.

From: Mr M. R. M. Cooper

(i) Experience

When marketing LR's verification capability, we should note that our experience is growing all the time. In addition to the twelve new construction projects listed in the LRTA Paper, work is being carried out from our Aberdeen and Lowestoft offices for verification of existing installations in the North Sea.

As well as working for oil companies, such as Amoco, we are also dealing with operating contractors, such as Atlantic Power and Gas, who manage offshore installations on behalf of some of the smaller oil companies, and with FPSO operators such as Bluewater. In the Southern North Sea, we have recently secured the verification services contract for all Arco platforms, including those previously certified by our competitor, the Offshore Certification Bureau.

Competition in the verification market includes not only our traditional rivals: DNV, Offshore Certification Bureau and the classification societies (appointed as Certifying Authorities), but also major engineering consultants such as AMEC and AEA, and the oil companies themselves. If an oil company can demonstrate that it is using competent personnel who are suitably independent of design, construction, or maintenance, then it can perform "second party" verification. On this basis, it is reasonable to include the oil companies in our list of competitors. Shell for instance, are large enough to perform verification in-house, and have in place such a policy. Nevertheless, LR has been awarded the contracts to verify two new Shell projects, and also to provide verification services to the Shell in-house verification group.

(ii) What was "Wrong" with Certification?

To maintain the credibility of our past work carried out under the Certificate of Fitness regime, we must be able to answer the question: "What was wrong with certification?"

Lord Cullen, in the Piper Alpha enquiry, made no criticism of LR (the Certifying Authority). It is true that, in the UK, there was a complex split of responsibilities between several different government agencies and the Certifying Authority; a problem that other countries avoided. LR obtained a lot of its overseas business because these countries modelled their regulations on the best aspects of the UK system, and LR was subsequently able to export its UK expertise. A rational safety-based emphasis for the work is clearly more elegant than an empirical selection of critical items, but for the integrity of hardware systems, certification has stood the test of time – 25 years in the UK.

Taking the case of an installation which started its project phase under the old Certificate of Fitness regulations, but which must now complete under a verification scheme, how much certification work is acceptable for verification, and how much real new work is required?

To: Mr M. R. M. Cooper

As Mr Cooper points out, the test of credibility for certification will be the contribution such work can make to a scheme of verification for a new project installation which is subject to the transition from the old regime to the new.

It is our understanding that all of the work undertaken within certification can be acceptable for verification, providing the work contributes to a demonstration of the suitability of the items covered by that work to meet the agreed performance requirement. It should be noted that verification does bring LR into contact with a wider range of safety critical issues which were previously outside our remit as a Certifying Authority e.g., risers, flowlines and topsides, active fire systems, life saving appliances and collision avoidance aids. Accordingly, this extension of scope brings real new work to LR.

To establish the other real new work required for verification, the dutyholder will have to decide how much credit to give to the work done for certification. The proof of this exercise is the value the dutyholder ascribes to the work undertaken by LR within certification, i.e. whether this work is considered to adequately address the relevant safety critical issues. This assessment is made by the process of establishing the performance requirements from the Safety Case for each safety critical element, and then comparing this with the performance standard achieved under certification. Clearly, where a shortfall is identified the dutyholder will have to upgrade the certified performance standard, or justify a relaxation on the performance requirement within the Safety Case. Where an upgrade of performance is required, LR, as verifier, will be expected to undertake examination to determine the suitability of the subject structure or plant to the enhanced performance standard.

To date our experience indicates that dutyholders are placing very heavy reliance on the performance achievements of certification (including Class Rules). There are, however, examples where dutyholders are setting performance requirements across a range of safety critical piping systems (hydrocarbons), to find that some of the selected range, such as oil cargo transfer and export systems, have been certified to a lower performance standard (specifically LR Rules, piping systems Class III) based on working pressure and service temperature. On such issues the dutyholders have raised concern that the Class approach does not provide objective evidence of integrity checking proven by hydrotest and NDE, which would have been required were the system performance standard set at the international standard for topsides process piping (ASME ANSI 31.3B). This is not to say that the piping system will be inherently less safe, only that there exists a less rigorous auditable trail to verify suitability within the scheme of verification.

From: Mr P. N. Pappas

I would like to congratulate both Mr Campbell and Mr Sewell for sharing their experience of these new verification schemes and highlighting the potential for LR's activities in this field. I would like to ask a question which is primarily concerned with the evaluation of the risk of explosions. Namely, how is the blast overpressure evaluated in the early stages of design and to what extent is the structure analysed in order to assess its capability to resist such impulsive pressures?

To: Mr P. N. Pappas

To help answer this question, the experience of colleagues has been drawn upon. In terms of verification schemes, the explosion overpressures become objective figures which contribute to deriving performance standards for certain structures. Considering this, LR as an ICP must review the work done and comment on the results. There are some difficulties associated with this task. When setting performance standards for the structure and equipment under explosion loading, uncertainties in predictions need to be taken into account. Depending on feasibility, cost and criticality, it may be reasonable to design structures and equipment to withstand explosion loads in excess of those predicted. Where this is not feasible, the performance standard must be set, based on considerations of cost and risk benefit. Here the benefit predicted in terms of reduced risk to be gained by improving the blast resistance of structures and equipment may depend upon the level of analysis undertaken.

Explosion overpressures are usually modelled at several stages throughout the project. Different software may be used at each stage.

In the early stages, simple models would be used to assess the most appropriate layouts. For the current FPSO designs, explosion modelling concentrates on the turret deckhouse and process area, where it is considered that the greatest risk of explosion may occur. In the critical turret area, if this is at the forward end of the ship, some degree of enclosure is often required to protect against green seas. This additional enclosure is of no benefit when trying to reduce overpressure loads.

Factors such as ventable area, degree of congestion, exact point of ignition, explosive gases and their concentration, all have a bearing on the results

At an early stage where equipment layout is being considered, conservatisms such as the application of a quiescent stoichiometric ratio would be made.

The inherent assumptions made by the software must be recognised as far as possible. As the mathematical processes of the software are complex, the modelling options within the software are often simple. For example, when modelling an FPSO turret deckhouse a model would be prepared consisting of the extremes of the enclosure represented as a parallel sided box, filled with simple boxes representing the contents. Clearly, the structure may not be parallel sided and may involve piping, gratings and other less easily definable items which may influence the result.

Typically, a series of runs would be made to determine the most onerous ignition point. These initial runs may not be used to derive the design overpressure and may only be considered sufficient to compare design configurations to provide the most suitable layout. Many simpler models will only define the average overpressure experienced and may not quantify the result in terms of a pressure loading, in order to encourage the use of the software as a scoping tool only, rather than as a design tool.

When the most satisfactory overall layout has been derived, further modelling using more advanced software may be carried out to determine the anticipated numerical blast overpressure in the area.

In light of recent full scale model tests, there is now some uncertainty with respect to the validity of the outputs from explosion modelling software. The results of these model tests can be found in the Fire and Blast Information Group (FABIG) Newsletter, No. 18, published by the Steel Construction Institute. The reference is: "Offshore Fires and Explosion – The Industry Goes Full Scale"; the initial findings of *The Joint Industry Project on Blast and Fire Engineering for Topsides Structures* are provided therein.

Efforts therefore must be made to maximise the knowledge of the limitations of the software in order to provide the best possible results.

Following the derivation of the overpressure in quantitative terms, the result is used in the structural analysis and generally considered as a normal loading. For blastwalls, plastic limits are normally considered acceptable, depending on limitations on deflection.

Other options include examination of the structure and escape implications considering that the derived overpressures may have been incorrect. This type of study would typically examine the capacity of the structure in detail and aim to ensure that the structure fails in such a way as to limit possible escalations and minimise loss of escape route integrity. In this case a full plastic capacity analysis can be carried out for all of the structure involved.

Experience with Verification Schemes under new UK Offshore Regulations

by P. C. Campbell and H. J. Sewell



Peter Campbell graduated with a B.Sc in Naval Architecture and M.Sc in Marine Technology from Strathclyde University, Glasgow in 1981. He joined LR Offshore Division in 1989, having spent four years with Odeco (UK) as project engineer, as part of the owners site team during the new build of Odeco's Ocean Alliance semi-submersible drilling unit at Scott Lithgow, Greenock. Previously he spent two years with UIE (Scotland) at Clydebank, as a construction engineer, having joined them following a period with Scott Lithgow as a student and graduate engineer. He is currently Principal Surveyor of Field Services Department, Offshore Services within Industry Division, in which capacity he has responsibility for the management of new offshore construction projects Certification and Verfication services contracts.



Hector Sewell graduated from Newcastle University in 1990 and joined LR in the same year on the graduate training programme. After a period working in the Edinburgh office and also at LR Nigg with Highland Fabricators, he returned to Offshore Division Field Services to co-ordinate Certification contracts for offshore installations held by LR. He then spent a period in LR Esbjerg where he was responsible for the coordination of all newbuild contracts held by LR in Denmark. Mr Sewell returned to the UK and spent a year in the Marketing and Business Group tendering for new work before returning to his current position with contract management to work in SLP Engineering's offices to manage the MacCulloch Field Development FPSO Verification Scheme.

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Synopsis

This Paper is intended to bring the reader up to date with the recent major changes to the UK Offshore Safety Legislation. In particular, the change from Certification to Verification, how this affects LR, and how LR are responding by developing verification services to assist our clients in meeting their obligations under the new regulations.

Outlined are the fundamental changes brought about by the introduction of the Safety Case Regulations in 1992, and the latest revision to these provisions in 1996, which require the setting up of a Verification Scheme for each installation.

Also explained are the purpose of verification, and the issues which have to be addressed. A review of LR current experiences in performing verification, and the process and control arrangements used by LR to document the work within a scheme is also provided.

A glossary of terms used in this Paper is provided in section 16.

1 Introduction

Certification, in terms of UK SI (1974) No. 289, which has remained in force with periodic revision since 1974, has now been replaced as part of the sweeping changes to the offshore safety regime introduced by the HSE. These follow the recommendations flowing from the extensive public inquiry into the Piper Alpha incident in 1988 when 165 people lost their lives. The short term impact in terms of the overhaul to the legislation has been the subject of a previous LRTA Paper (Ref. [8]), to which the reader may wish to refer.

The most significant of these changes were the handover of regulatory responsibility for offshore safety from the Department of Energy to the Health and Safety Executive in 1991, and the bringing into force of the Safety Case Regulations, UK SI(1992) No.2885 for the purpose of enforcing the adoption of a more robust and formalised approach to the management of safety and hazards throughout the full life cycle of an offshore installation, and placing clear accountability for such matters with the owner or operator.

The latest regulation to support the Safety Case was introduced in 1996. It's provisions included for the revocation of the Certification scheme, replacing it with the requirement for the safety critical elements (SCE) of an offshore installation to be verified as suitable by independent and competent persons. So the requirement for a Verification scheme was born.

The scheme has been drawn up and introduced following widespread consultation with representatives of the industry associations representing offshore operators and contractors, trades unions representing the offshore workforce and other interested organisations including LR and government departments. LR continues to play an active part in the process of developing guidelines on the drawing up and implementing verification schemes, by participation in the current Industry/HSE liaison working groups.

The scheme for each installation will be the responsibility of the duty holder who will appoint the independent competent body in the capacity as verifier. LR are not therefore delegated by the regulator to provide verification services, but must secure this work from the duty holder on the basis of bringing LR's collective experience and expertise together to add value to the duty holders system of safety and hazard management during the lifetime operation of an installation.

Figure 1 summarises the extent of LR's verification services to date.

Project	Description	Client	Service	Start Date	Finish Date
Galleon PG	Fixed Platform	Shell Expro	New **Verification** scheme	1996	1997
Marathon West Brae & Sedgewick	Subsea Facilities	McDermott Marine Construction Ltd.	New **Verification** scheme	1996	1997
BP Bruce Phase II	Fixed Platform	John Brown Offshore	New **Verification** scheme	1996	1998
Schiehallion	FPSO	Atlantic Frontier Alliance	New **Verification** scheme & Certificate of Fitness	1995	1997
BP ETAP	Fixed Platform & Subsea Facilities	BP Exploration Operating	New **Verification** scheme	1995	1998
Shell ETAP	Subsea Facilities	Shell Expro	New **Verification** scheme	1995	1998
Conoco MacCulloch	FPSO	SLP Engineering	New **Verification** & class	1995	1997
Durward/Dauntless	FPSO, Subsea Facilities & Pipelines	Bluewater Engineering Kvaerner H & G Offshore	New **Verification** scheme, class & Cert. of Fitness	1995	1997
Curlew	FPSO, Subsea Facilities & Pipelines	MAS Alliance	New **Verification** & class	1996	1997
Liverpool Bay	Fixed Platform, Jack-up & FPSO	BHPP	Cert. of Fitness & in-service **Verification** scheme	1993	1995
Erskine	Fixed Platform	Texaco North Sea UK Ltd.	Cert. of Fitness & in-service **Verification** scheme	1995	1997
Armada	Fixed Platform	British Gas	Cert. of Fitness & PFEER	1994	1997

Figure 1
Verification Scheme experience

2 Regulation Overview

The Safety Case regulations which came into effect in 1992, are the focal point of the offshore safety regime, and were introduced to ensure a more effective process for identification and management of hazards, and the evaluation of associated risks in an offshore environment.

To complement the provisions of the Safety Case, there are now also a number of additional underpinning Regulations, which have been introduced both to amplify and add more specific requirements. The theme which extends throughout the Safety Case and the underpinning regulations is the process of Hazard Management. These supporting regulations which contribute to this process are identified as follows:

- SI (1992) 2932 PUWER: Provision and Use of Work Equipment Regulations
- SI (1995) 743 PFEER: Prevention of Fire, Explosion and Emergency Response Regulations
- SI (1995) 738 MAR: Management and Administration Regulations
- SI (1996) 825 PSR: Pipeline Safety Regulations
- SI (1996) 913 DCR: Design and Construction Regulations

The relationship between these supporting Regulations and the Safety Case may be represented as in Figure 2.

The latest of the above provisions to support the Safety Case, and the one which embodies the requirement for Independent and Competent Verification, is the DCR SI (1996) 913, which came into force on June 10th 1996.

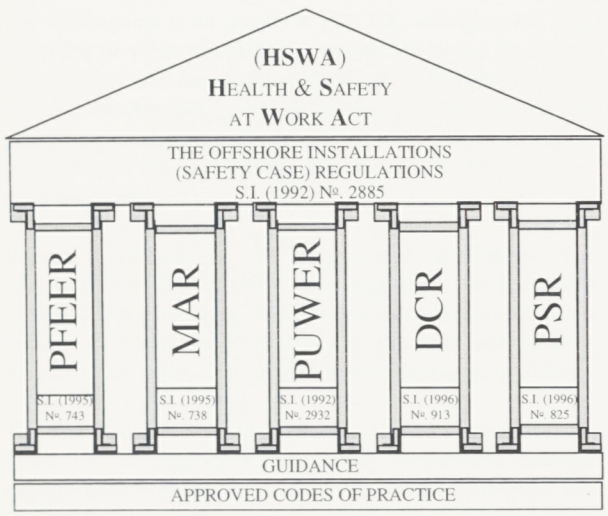


Figure 2
Regulations underpinning the Safety Case Regulations

3 DCR and the Requirement for Verification

The DCR is concerned with the integrity of offshore installations, the safety of wells, the workplace environment offshore, and the suitability by verification of safety critical elements of an offshore installation.

The 5 parts are arranged as follows:

- Part I, Interpretation and General (Regulations 1 to 3),
- Part II, Integrity of Installations (Regulations 4 to 10),
- Part III, Further Requirements Relating to Installations (Regulations 11 and 12 and Schedule 1),
- Part IV, Wells (Regulations 13 to 21),
- Part V, Miscellaneous (Regulations 22 to 27 and Schedules 2 & 3 including the requirement for verification).

In summary, the DCR requires that an installation is designed, constructed, operated and decommissioned, such that, so far as reasonably practicable:

- the installation possesses integrity(structural soundness, strength, and, in the case of floating installations, buoyancy)
- safe helicopter landing areas are provided on the installation
- miscellaneous workplace environment provisions are complied with by 3 November 1999
- there can be no unplanned escape of fluids from a well
- there are suitable arrangements for examination of wells
- risks associated with all aspects of a well are As Low As Reasonably Practicable (ALARP)

It should be noted that although the requirement for verification has been introduced within the DCR, the DCR has the effect of amending the Safety Case Regulations by placing the requirement for verification firmly within the provisions of the Safety Case. It is intended that the stand alone HSE Guidance on verification will in due course be included in revised Safety Case Guidance.

In relation to the requirement for verification, the duty holder must ensure that the principles for selecting independent, competent person(s) are established and that the following issues are addressed by or in consultation with such a person(s):

- a record is made of all the safety critical elements
- a verification scheme is prepared and put into effect for the life of the installation
- a note is made of any reservations expressed on the record or the scheme by the independent and competent person(s) and
- the scheme is continuously reviewed and, where necessary, revised or replaced.

Under this legislation, it is the responsibility of the duty holder of a fixed installation, and the owner for mobile installation, to cause the establishment and implementation of an ongoing verification scheme for safety critical elements relevant to that installation.

To assist dutyholders to fulfil their obligations in respect of implementing a scheme, the HSE has published Guidance, which summarises the matters to be included in a scheme, and how the work performed within the scheme relates to other regulation requirements.

Definitions: (from HSE Guidance)

Safety Critical Element

"'Safety critical elements' means such parts of an installation and such of its plant (including computer programmes), or any part thereof –

(a) the failure of which could cause or contribute substantially to, or

(b) a purpose of which is to prevent, or limit the effect of, a major accident."

Major Accident

A major accident' is:

"(a) a fire, explosion or the release of a dangerous substance involving death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;

(b) any event involving major damage to the structure of the installation or plant affixed thereto or any loss in the stability of the installation;

(c) the collision of a helicopter with the installation;

(d) the failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operation or the trapping of a diver in a diving bell or other subsea chamber used for such operations; or

(e) any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity connected with it."

4 Purpose of Verification

The overall objectives of a verification scheme may be summarised as follows:

- To replace the Certification Regime of SI 289
- To set in place Independent and Competent scrutiny of parts judged to be safety critical
- To ensure their appropriate examination to confirm suitability
- To provide assurance that they remain in satisfactory condition
- To establish a scheme for the full lifecyle management of such examinations
- To provide the duty holder with an important component of a Safety Management System (SMS).

5 Difference between Certification and Verification

Verification is not certification under a new name. Under the certification scheme in terms of SI 289, the Secretary of State empowered six organisations (five of which were marine classification societies) to act in the capacity of Certifying Authority (CA). In this role, the CA's were acting as agents to enforce the provisions of the supporting guidance to the regulations as they saw fit for the purpose of issuance of a Certificate of Fitness with a validity of five years, subject to satisfactory periodic survey.

Under the Safety Case Regulations, amended in 1996, it is now the duty holder's responsibility, as part of the process of hazard management, to set in place a verification scheme for the purpose of ensuring the continued suitability of the safety critical plant and structure by ensuring scrutiny by independent and competent persons.

For the duty holder, the scheme will contribute to his responsibility under the Safety Case Regulations to implement Safety Management Systems.

The big difference for LR is that, as an Independent Verification Body (IVB), we are engaged as a contractor by the duty holder to provide Independent Competent Body services, not as an agent of the regulator.

The duty holder can engage one or any number of IVB's to contribute to providing verification services within the duty holder's scheme. There is of course a danger for the duty holder should they adopt multiple IVB's, in that fragmentation introduces additional interfaces for which the duty holder would be responsible and require to be able to demonstrate they were managing within the scheme.

The distinction to be made is that LR, acting as an IVB, provides services to verify the suitability of the design or construction of a component or system or the entire installation as contracted by the duty holder, but does not, on providing verification services, have a duty to assure compliance with the regulations, this being the duty holders responsibility.

Within Certification, the assessment of 'Fitness for Purpose' was based upon checking that the hardware integrity complied with the provisions of an international code or standard considered as best practice, and the provisions of the HSE Guidance Notes accompanying SI 289.

The limitations of integrity checking alone have been recognised by the regulator, hence the Verification Scheme requirement that the verifier checks not just integrity but 'suitability' to manage the hazards, which is defined as being appropriate, dependable and effective when required, and having the ability to perform as intended.

The Certification scheme was one element of a fragmented approach to the management of offshore safety. A feature of this fragmentation was the split of responsibility in relation to fire fighting provisions, in terms of UK SI (1978) N°611, Fire Fighting Regulations. The provision of this Regulation made the Certifying Authority responsible to verify the basic integrity, ie. materials, workmanship and power supplies of the fire fighting systems, whereas the verification of the performance requirements ie. pump capacity, supply rates etc., were the responsibility of the UK DoT.

Such anomalies have been removed by the revocation of these regulations, with the responsibility for these provisions within the DCR, now resting with the duty holder to include these aspects within the installation verification scheme, such as they may be safety critical.

6 Transition Arrangements

Although the requirements for the setting in place of a verification scheme became effective in June 1996, and applies both to new and existing installations, duty holders in possession of valid Certificates of Fitness, or having applied for one before June 1996 are entitled to make use of a two year transitional period. In essence, adherence to the provisions of SI (1974) 289, will, for the duration of the transition period, be regarded as an adequate substitute for the verification scheme.

Fixed and mobile units are dealt with separately, because they may come into UK jurisdiction at different stages. For a new fixed platform, a verification scheme is required to be put in hand before the completion of design work. For a mobile installation, the requirement for a verification scheme takes effect when it enters UK waters, but duty holders are expected to understand that they will need to be able to demonstrate the adequacy in all respects, including matters relating to design, construction and unit history, before entering UK waters. It is anticipated that Class and Flag State surveys and certification will contribute to this demonstration.

If a Certificate of Fitness expires without replacement, or is terminated for any reason before the two year transition period has passed, the duty holder is required to comply with the verification requirements.

The change to the new verification scheme must take place before June 1998. Duty holders may select an earlier time to change to verification in consultation with the Certifying Authority.

It should be noted that it is only the requirement for verification to which the transition period relates, not the integrity requirements of the DCR which came into immediate effect. Duty holders need to be aware that the integrity requirements may, in some instances be more stringent than under the requirements of SI 289.

7 Key Elements of a Verification Scheme

A verification scheme is required to address the following key elements:

- The principle applied in selecting independent and competent persons to operate and review the scheme
- The provision of a record of safety critical elements, including comments or reservations expressed by the independent and competent person reviewing the record.
- The establishment of appropriate standards of performance for the safety critical elements
- A criticality assessment of safety critical elements and the development of the means of verification, including breadth and depth of examination of design, inspection and test, examination of work in progress, the type and periodicity of examination, and arrangements incidental to the examinations
- The assessment of suitability of safety critical elements of the structure, facilities and equipment against the agreed standards of performance
- The preparation of a suitable written scheme of verification
- Provision of arrangements for review and revision of the scheme
- Provision of arrangements for recording the results of examinations, findings, and recommendations
- Provision of arrangements for implementation or close-out of recommendations
- Provision of arrangements for communicating between verification activities and the project's Safety Management System (SMS) whilst the Safety Case is prepared.
- Overall management of the verification scheme, audit trails, records, certificates and reports to management.

8 Relationships with other Regulations, Legal or Voluntary Requirements

It is intended that the verification scheme may take into account work done to satisfy other legal or voluntary requirements such as classification of a fixed or mobile installation, or declarations of conformity with European product legislation. Duplication of any work done is to be avoided, as long as it can be demonstrated as suitable contributory material to the verification scheme. The duty holder will be responsible to ensure that it is sufficient for the purpose of compliance, and to decide what additional measures may be needed to complete the verification work.

On account of the limited duplication which still exists within the current framework of the Safety Case regime, some plant which is selected as being safety critical will also be subject to the written scheme of examination required by PFEER Reg. 19 (2). Arrangements for the verification of the suitability of such plant are expected to give credit for the examination carried out to achieve PFEER compliance.

Also, where a well is associated with an installation, and where parts of the well are judged to be safety critical and requiring verification, work done to achieve compliance with the well examination scheme (also required by DCR, and not part of verification), may contribute to the installation verification arrangements.

Whatever the process set in place for the assignment of the examination, design review and survey activities, LR will use it's experience to provide an efficient integrated and holistic examination service to address the overlaps between the Statutory (Flag), Class, PFEER, DCR Wells and verification regimes (as applicable), to avoid duplication of effort.

9 Contribution of Class and Flag

9.1 Class

The use of classification within the offshore sector is well established and understood by owners of mobile units, who rely on classification both for the purposes of securing their freedom to operate and transit in international waters, and as means of assuring their integrity in design , construction and in service suitability by means of periodic condition survey. Such owners, who will become duty holders when the unit operates as an installation in UK waters, are understood to be entitled to gain maximum credit within their required verification scheme, from the work already performed for classification, on the basis that classification can provide an adequate basis for demonstrating that the identified safety critical elements addressed by class, are and will remain 'suitable'.

For owners/duty holders of floating production, storage and offloading units (FPSOs) which operate possibly at a single fixed location within UK waters for their entire operating life, classification is not a statutory requirement, therefore a duty holder is unlikely to adopt such a voluntary provision unless there is a demonstrable case that adopting classification will contribute more than another method, toward achieving compliance within a verification scheme.

Our recent experience with duty holders of FPSO's indicates that the Classification requirements in relation to the vessel hull, essential marine systems and moorings, embraced within LR Rules for Fixed Installations, Part 9, are providing an adequate basis to establish a performance standard for these elements within a scheme.

The class system also has the merit of well established survey procedures, a reporting system to record the findings of ongoing examinations, and a diary system to ensure implementation of corrective actions, all of which is consistent with the overall objectives of the verification scheme.

The reliance that duty holders of mobiles and the growing fleet of FPSO's may place on classification is clearly an encouraging area of business for LR at this uncertain time when Certification work will inevitably cease. The challenge for LR is to continue with Classification Rule development which embraces the hazard management approach to ensuring suitability, which will deliver classification and compliance with the UK Safety Case provisions without duplication of cost. In particular LR will need to focus on how to harmonise the survey requirement for Class with our duty holder client's minimum requirement for verification, within which the verifier (LR) will be expected to give substantial credit for examination activity by others, which under traditional class work, may have been the exclusive territory of the LR surveyor.

Where Class Rules are expected to contribute to verification of an FPSO unit, the typical range of categories of safety critical elements applicable to an FPSO unit, and the integrity standards underpinning their performance are provided in Figure 3.

9.2 Flag

Just as flag administrations may rely on class to address the requirements of the IMO Conventions of SAFCON and Loadline, the duty holder of a flagged offshore unit will be entitled to take credit within verification from the IMO Conventions compliance, where the performance achieved is "suitable". It is understood that the provisions of MARPOL, from stability aspects, are considered by duty holders to be an appropriate standard. The provisions of SOLAS 1974, as amended, for Safety Equipment and Safety Radio may provide a suitable prescriptive standard, but is considered to require the support of thorough project specific safety studies to validate that these risk based design safety/protection systems can provide suitable performance, particularly in the context of availability and survivability.

The contribution made by class and flag in the case of a typical FPSO unit is shown diagramatically in Figure 4.

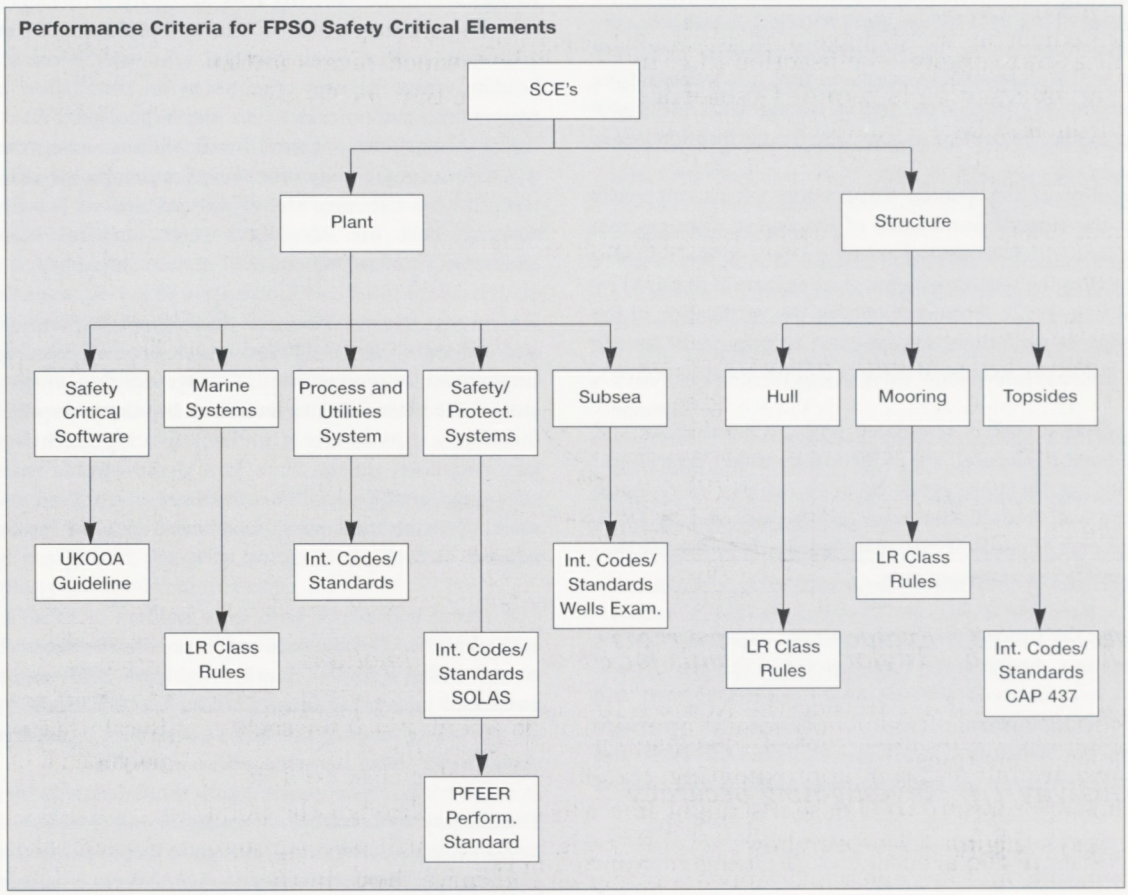


Figure 3
Typical Integrity Standards

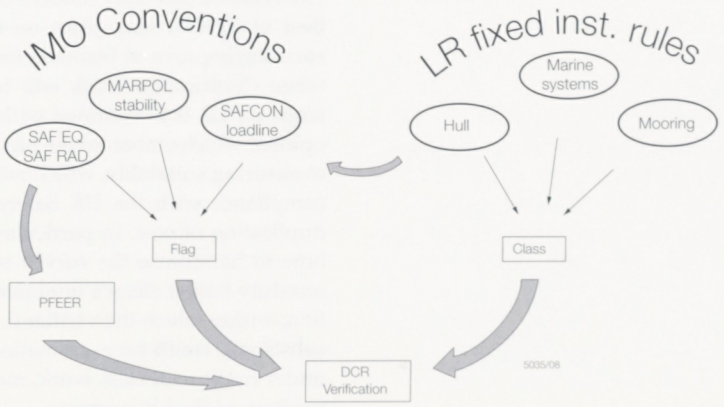


Figure 4
Contribution of Class and Flag

10 Development of services

The move away from Certifying Authorities to Independent and Competent Bodies undoubtedly opens up verification work to more competitors. This includes schemes also being developed and managed from within the duty holder's own organisation provided he can demonstrate independence where required.

However, there are a number of factors which work in LR's favour. The first of these is our obvious demonstration of independence and competence.

The recent popularity of FPSOs allows us, along with other International Association of Classification Societies (IACS) members, to offer class and selected statutory services alongside the verification process. LR Offshore Services has emphasised the contribution Class can make in the setting of appropriate performance standards and also to the retained value of FPSO type installations which are often intended to be moved to a new field location during their full life cycle.

The message is very much that where verification is undertaken by IACS members, the activities carried out under verification can contribute to Classification.

Our strong world wide organisation is a significant strength when offering verification services for new build projects. It can also be a major benefit which allows LR local offices to participate effectively in more fragmented verification schemes not necessarily under the overall stewardship of LR.

The new regulations are focused on safety critical elements. This may eventually reduce some of our traditional areas of involvement at least with some of our clients. However we are also able to expand the range of services to additional areas such as pipelines within 500m of installations and safety critical software verification.

The verification work scope must be derived on the basis of objectivity, risk and consequence. Independent technical review is therefore always clearly identified as being required and adds value to the project by providing welcome technical review where most beneficial.

11 Scheme Development

11.1 Routemap of a Verification Scheme

A typical routemap of the verification process is shown in Figure 5.

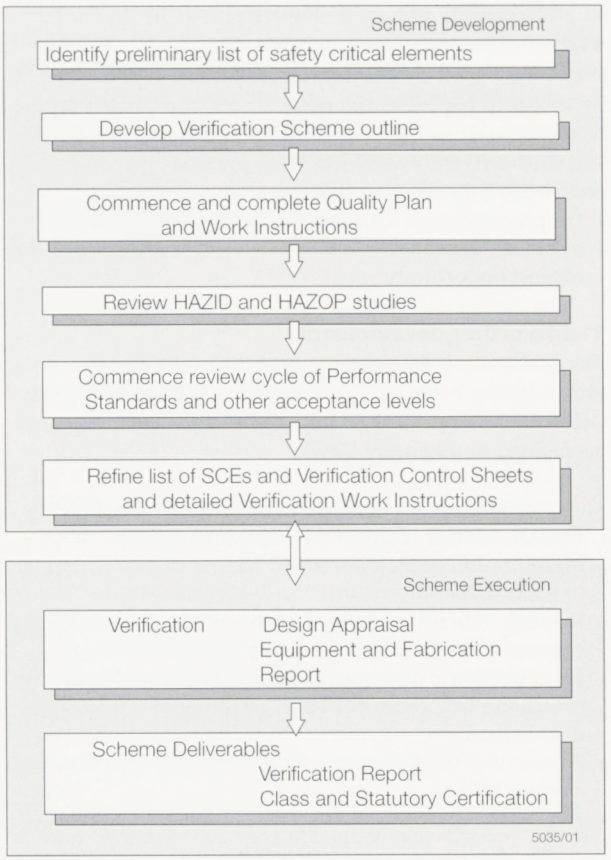


Figure 5
Typical Routemap

Successful implementation of the verification work within the scheme relies on the orderly cascade of deliverables derived from the formal safety assessments and studies performed within the Safety Case. Foremost will be the work done on the identification of hazards with the potential to cause or contribute to a major accident, which will enable the accurate identification of the safety critical elements for the installation.

A detailed assessment by the IVB of the methodology used to identify the safety critical elements is not required, only that the IVB comments on the record of elements and that a reservation is recorded in the event of disagreement with the duty holder.

11.2 Process of selecting Safety Critical Elements

The guidance notes for SI 913 state:
"The identification of safety critical elements is crucial to the effectiveness of the scheme. The responsibility for the list of safety critical elements will rest with the duty holder. Regulation 15A requires the opinion of an independent and competent person to be sought where this identification has not been carried out by such a person."

The derivation of the list can involve the following processes:

11.2.1 Preliminary lists

Preliminary generic lists may be prepared by the verifier or by the duty holder in the early stages of a project on the basis of engineering judgement, engineering experience and feed forward experience from previous projects. They are particularly useful at this stage for:

- the preparation of LR's bids for verification work
- initiating appropriate actions in vendor's works at the earliest opportunity.

11.2.2 Further development

The preliminary listing must be further developed into a formal listing based on consequence of failure with potential to cause, contribute or mitigate a major accident event, (as defined in the Safety Case).

The selection process of SCE's must include the following:

- Identification of limits of the installation
- Identification of major accident hazard causes particular to the installation
- Identification of structure and systems whose failure could cause or contribute to these major accident hazards
- Identification of other parts whose failure would indirectly contribute to a chain of events resulting in a major accident hazard
- Application of engineering judgement and experience as a cross check
- Application of feedback from Safety Assessment Studies.

Where the failure of a component part or system could cause or contribute to a major accident hazard, or where such an element is required to mitigate against a major accident hazard, then such an element must be considered safety critical. Where LR, as the independent and competent body, is involved with the derivation of the safety critical elements we must interrogate the formal safety assessments and the safety case to begin to make an accurate determination. As an example of this process, Hazard Identification (HAZID) studies can be arranged to provide a ranking of equipment and systems based on consequence of failure. Early in the derivation, the list may stay at the system level and then later descend to a system component level as the feedback from formal safety assessments provides more focus on the weaker links within the safety chain.

Identification of safety critical elements can be achieved more readily if it is seen as a stage in the overall process of hazard management rather than as an end in itself. The record of safety critical elements should not be prepared in isolation, on the basis of only limited experience. Rather the record should be the natural product of the knowledge and understanding developed during the identification of hazards (e.g. the HAZOP studies) and the evaluation of risks carried out for the safety case. This needs to be reviewed and revised accordingly to ensure that it remains up to date.

11.3 Setting Performance Standards

A Performance Standard is the criteria that is set to achieve the lifetime suitability of the safety critical elements. Suitability in this context is benchmarked as being:

- appropriate for intended use
- dependable and effective when required
- able to perform as intended.

Performance standards are set as the basis for managing the hazards and for confirming that systems are effective in delivering the required reduction in risk.

Performance standards need to be set in a way which will assist those responsible for operating, maintaining and examining a system, and in taking decisions about its adequacy to perform it's required role. In addition, rigorous assessment helps to identify weaknesses and enables an understanding of the causes and characteristics of different types of hazardous event. This understanding forms the basis for the development and implementation of an effective and efficient hazard management system. Performance standards should embody the best information available about the systems concerned.

A simplistic three stage approach to the development of performance standards for safety critical elements of plant and structure would be as follows:

- adopt an established standard for component or system integrity (i.e. conformance with a recognised code or standard)
- assess and identify any hazards to be managed that the basic component or system integrity would not normally address. The findings in the following safety studies will be used to highlight these issues.
  - HAZOP report findings
  - Fire and Explosion risk analysis
  - Dropped object study
  - Temporary refuge impairment study
  - Smoke and gas ingress study
  - Escape, evacuation and rescue study
- supplement the development of the performance standard for PFEER plant equipment items to address:
  - functionality
  - availability
  - reliability
  - survivability
  - interaction

LR as an IVB can contribute to the conduct of this work where contracted to do so. As an IVB, the minimum role for LR would include identification of errors or failures in the selection of the appropriate performance standard.

11.3.1 Verification Effort

Having established what is safety critical, and the performance requirement, the next stage is to develop a method for assigning the breadth and depth of examinations to verify suitability. One method being adopted by duty holders

is to use a system of criticality ranking, formed from an assessment of the consequence of SCE failure and the likelihood of such a failure being realised during the life cycle. This can be represented in tabular form in Figures 6 and 7.

Consequence Ranking	
5 CATASTROPHIC	Multiple deaths
4 FATAL	Single death
3 MAJOR	Multiple severe injury
2 SEVERE	Single severe or multiple minor injury
1 MINOR	At most a single minor injury
Likelihood Ranking	
5 FREQUENT	Likely to occur repeatedly
4 PROBABLE	Likely to occur from time to time
3 OCCASIONAL	Likely to occur once
2 REMOTE	Unlikely to occur
1 IMPROBABLE	Very unlikely to occur

Figure 6
Verification Effort 1

Likelihood	Consequence				
	1	2	3	4	5
5					
4					
3					
2					
1					
		L		M	H

Figure 7
Verification Effort 2

The process involves the pooling of these rankings to create a criticality ranking which is assigned within the range of high, moderate or low. The examination breadth and depth is then assigned to each rank. SCE's scoring a high rank are subjected to the closest independent scrutiny, to verify the issues which bear most heavily on their capability to fulfil the performance requirement. The assignment of examination activity so derived is shown in matrix form in Figure 8.

Ranking	Examination Activity	
	Design Review	Construction Survey
High	• specification • strength • containment • layout • protection • controls	• review • Quality Plan and Procedures • Manuf. doc. of comp/matls. • spot check manufacturing process • selective witness integrity tests • witness function/performance tests
Moderate	• specification • selective document review	• review • Quality Procedures • Manufacturer's documentation • witness factory acceptance testing
Low	• specification • technical audit	• review • Certificate of Conformity • EU Declaration

Figure 8
Verification Effort 3

Following on from the above ranking process, or other agreed method if any, LR as the verifier will use its surveyor's professional judgement and experience to tailor the examination depth to account for the following factors:

- novelty of design or application
- complexity of design or manufacture process
- track record of manufacturer/supplier
- historical failure rate data
- EU conformity or type approval/certification
- examination already performed by other competent persons

Verification survey examination is not intended to be inspection. As with the existing Certification scheme, survey is intended to be undertaken on the basis of monitoring surveillance to verify that the manufacturer/supplier is implementing suitable quality procedures for the control of the work, with suitably qualified personnel, to be satisfied that on completion, the equipment or system conforms to the project performance standard.

12 Scheme Control

LR have found that providing a dedicated Verification Project Manager for the verification activities is both cost effective for the project and brings considerable benefits. Wherever possible, the verification project manager is based in the project team's office and is fully integrated into the project team. This greatly improves communication and document turnaround times and yet still achieves the independence required by the legislation.

In order to assist the verification project manager with control of the verification activities the following documents have been developed:

12.1 Verification Scheme Matrix

A Verification Scheme Matrix can be developed to provide a management tool which illustrates the overlap between the regulations underpinning the Safety Case Regulations by showing the relationship between the Safety Critical Elements (SCE's) and DCR/SCR, PFEER, DCR Wells Examination, Class, and Flag State requirements (where applicable).

This assists LR in establishing an integrated Verification service which will address the design review and survey requirements to meet all applicable regulations.

The matrix facilitates the identification and segregation of verification activities which can also be used for contract control purposes. This is particularly useful with alliance type projects where different parts of an installation are often covered by separate verification services agreements. This feature can also be used to define items which are covered on a local order basis for example pressure vessel manufacture.

It has also been found beneficial for SCE's identified in the verification matrix to be cross-referenced to the actual project system numbering in order to identify SCE's using equipment list numbers and purchase order numbers (which links verification activities to sub-contractors). It is also important for existing installations in order to identify SCE's using Maintenance Management System (MMS) numbers.

An example of a verification matrix is provided in Annex 1.

12.2 Verification Control Sheets (VCS)

As a management and reporting tool, and developed to provide control and monitoring functions, Verification Control Sheets have been used for several of the current verification contracts.

The term Verification Control Sheet (VCS) is LR's own, however in some instances clients have developed their own documents with different names but with similar objectives.

The VCS's are a means of providing interested parties, such as design review specialists, surveyors or equipment manufacturers with a reference document. The VCS's provide, for each safety critical element:

- reference to the accepted performance standard.
- reference to the detailed scope of work for verification. This may be by further reference to detailed Work Instructions, (VWI), equipment manufacturers marked up quality plan or other.
- a mechanism to track and monitor the progress of verification throughout the project phases in terms of verification records. (Comment Response Sheets, Inspection Release Notes, Endorsed Mechanical Completion and Commissioning Reports).
- an audit trail for monitoring progress and demonstrating compliance.
- documentation for the final verification report which will form part of the Safety Case documentation.

An example Verification Control Sheet is provided in Annex 2.

The control sheets can be collated and catalogued in logical packages. Figure 9 illustrates a typical breakdown.

12.3 Verification Work Instructions

Since the verification examinations are being undertaken within the dutyholders scheme, it is considered important that LR provide visibility and auditability of the type, extent, and process of examinations. To this end LR have developed a detailed Verification Work Instruction (VWI) template for each safety critical element.

The VWI provides the link between the agreed performance standard and the LR design review and survey activities, to ensure that the examination activities are focused on the issues which bear most heavily on capability to fulfil the performance requirement.

The VWI content is developed taking account of any agreed process of safety criticality ranking, and is intended to provide an integrated examination scope to address any overlaps in the applicable regulations or project requirement of Class/Flag.

An example of a typical Verification Work Instruction is provided in Annex 2.

12.4 Summary of Control Methodology

An illustration of a typical control system is provided in Figure 10.

The diagram illustrates how an examination of Safety Case related formal safety assessments – the *verification audit* – is used to develop the scope of work for verification by providing input to the development of verification control sheets, detailed work instructions and leading to the issuance of appropriate release certification.

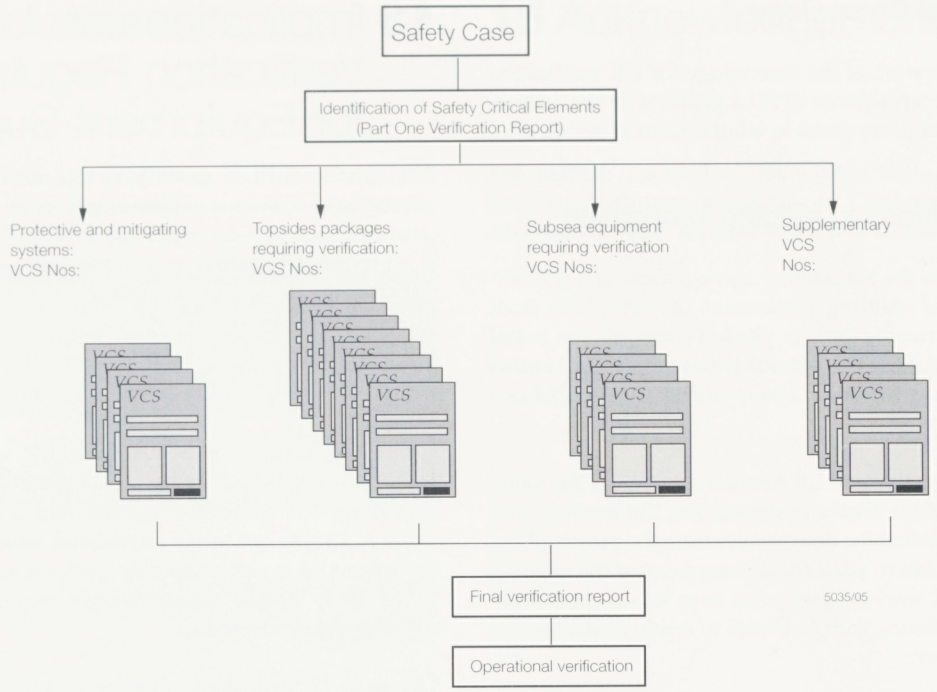


Figure 9
Verification Control Sheet Catalogue – Typical Structure

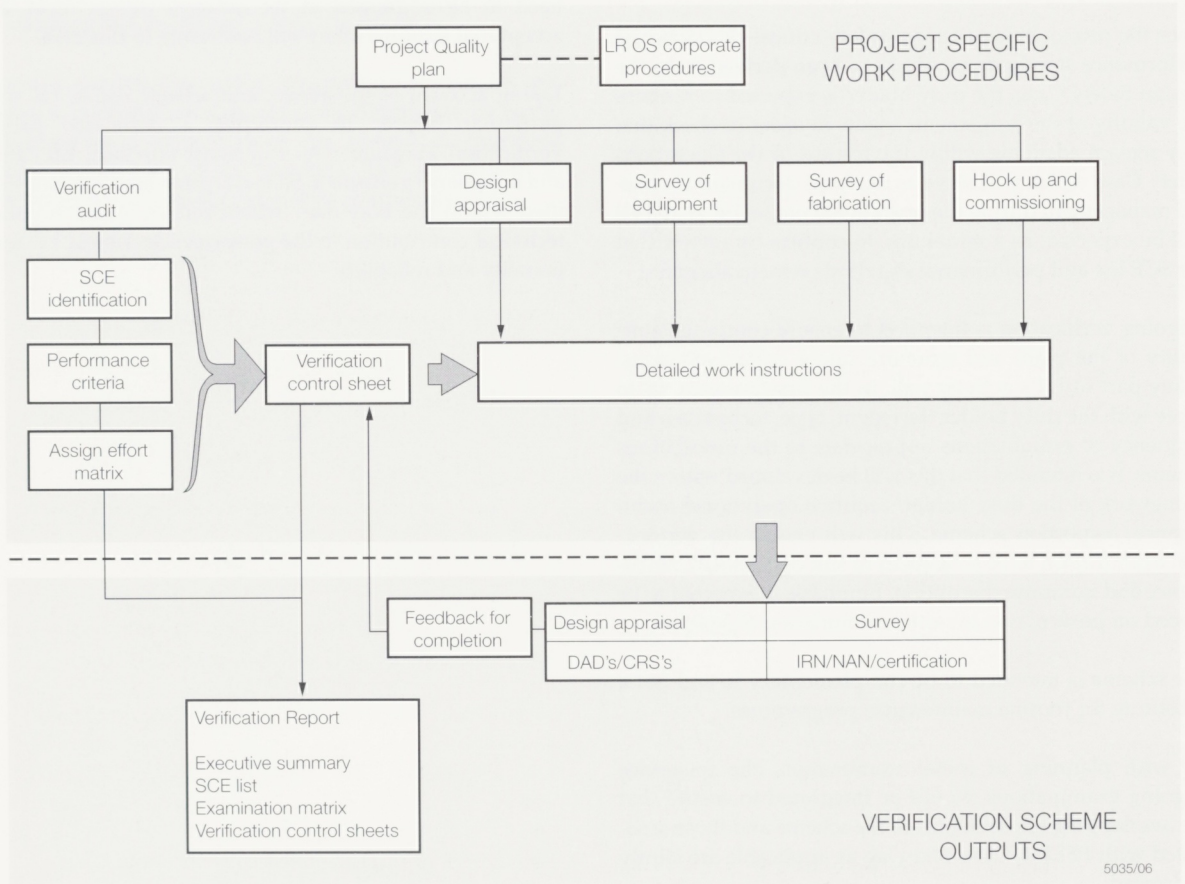


Figure 10
Verification Control Methodology

12.5 Typical Chronology

A typical illustration of the chronology for UK verification and class acceptance for an FPSO together with the deliverables at each stage are given in tabular form in Annex 3.

12.6 Transition to Ongoing Verification

Fundamental to the satisfactory management of a full lifecycle scheme is ensuring progression of verification from the new construction project phase (where all the initial examination work is performed) through into the normal operations phase, where the scheme development reaches a mature steady state.

LR Offshore Services and LR Aberdeen recognise the value to our duty holder clients of dovetailing the services provided, to ensure that the deliverables from the project phase will be compatible to assist the development of the ongoing scheme. An LR working group has been set up specifically to look at the issues with potential to create obstacles to a smooth handover.

The key handover document within the scheme will be the Verification Report which will contain a summary of the key inputs and deliverables, including any particular reservations or anomaly reports indicating aspects of the work either uncompleted or not conforming with an agreed performance standard.

Since the project phase (design) safety critical elements and performance standards would have been derived from the Design Safety Case, the duty holder is expected to reassess the validity of the judgements made, in order to check that they remain adequate within the context of the Operations Safety Case which will serve as the focal document for hazard management during the operational phase. LR as an IVB will be expected, as a minimum, to confirm by review that the SCE list and performance standards remain adequate.

Ongoing verification is intended to ensure continued suitability of the plant and structure safety critical elements. A key part of LR's activity will, in the first instance, be to agree with the duty holder the extent, type, techniques and frequency of examinations appropriate to the installations scheme. It is intended that this will be developed within the framework of the duty holder's routine operational maintenance/inspection scheme. This will enable the verification examination to be scheduled to suit operational convenience and minimise disruption. Emphasis is expected to be placed on proven, non invasive examination techniques.

The scheme is intended to be complementary to and not a substitute for routine maintenance programmes.

As with planning of initial examination, the in-service ongoing examinations should be integrated to ensure that the overlapping requirements of the scheme and those associated with PFEER, Class and Flag as applicable are jointly addressed.

13 Implications of Verification Regulations for Equipment Suppliers

Under the Certification scheme, it was common practice for suppliers to contact local LR offices for the purpose of engaging certification services, secure in the knowledge that fitness for purpose could be achieved at a local level without reference to the purchaser or other party.

Under the verification regulations, the supplier cannot make this assumption unless, or until the duty holder representative (i.e. purchaser) has clarified if elements of the scope of supply are safety critical and which are therefore the subject of a project specific performance specification which may include supplementary requirements to the supplier standard product.

This issue is particularly relevant for the supply of safety protection systems equipment, where a key component of performance may relate to availability and survivability, neither of which the supplier has any jurisdiction over.

In such cases, the duty holder representative must recognise that the gaps in the demonstration of suitability will need to be addressed at the systems design level, and accept that suppliers may not contribute to this area.

Taking account of the above, and related issues, LR see a particular benefit to providing a dedicated project Verification Manager who can assist our local LR offices and suppliers to ensure local verification activities are specified within the boundary which relates to the suppliers technical contribution to the performance criteria, i.e. functionality and reliability.

14 Conclusions

Verification schemes are very much in their infancy, and this Paper documents our current experiences in providing services tailored to meet our client specific requirements. Schemes for new installations are being developed on a project by project basis by the duty holder, within a framework depending on the duty holders resource availability to implement the work in-house, and/or their intention to rely on the allocation of some of the key tasks associated with the scheme development to other competent persons, such as LR. It is not expected that all the schemes would be the same, indeed duty holders are free to implement schemes as they see fit to comply with the goal of the verification regime.

As mentioned within the Paper, the recent predominance of new projects utilising FPSO solutions for field developments has had a bearing on the demand for LR's services on the strength of the case for using classification as an appropriate performance standard for the hull, moorings and marine systems.

LR have also benefited from a substantial carryover of goodwill from the performance of our services under the Certification regime, and from our clients belief that our competence and independence will prevail irrespective of the statutory safety regime in force on the day.

To ensure the development of this business stream, LR will require to demonstrate that our skills continue to be worth harnessing in contributing to the hazard management process within our clients business, and assist them in achieving and maintaining statutory compliance.

15 Acknowledgements

The authors gratefully acknowledge the assistance they have received from colleagues in Offshore Services and Aberdeen for their support in the preparation of this Paper.

16 Glossary

ALARP	As Low As Reasonably Possible
CA	Certifying Authority
COF	Certificate Of Fitness
Duty Holder	The operator of a fixed installation The owner of a mobile installation
Operator	A person appointed by the con cession owner to execute any function of organising or supervising any operation to be carried out by such installation or, where no such person has been appointed, the concession owner
Owner	In relation to a mobile unit, the person who controls the operation of the installation
DCR	The Offshore Installation (Design & Construction etc) Regulations
EID	European Union Extractive Industries Directive (No.92/91/EEC)
FPSO	Floating Production Storage and/or Offloading
HAZID	Hazard Identification Analysis
HAZOP	Hazard and Operability Analysis
HSE	Health and Safety Executive
HSWA	Health and Safety at Work Act 1974
ICP	Independent and Competent Person
IRN	Inspection Release Note
IVB	Independent Verification Body
MAR	SI 738 Management and Administration Regulations
MMS	Maintenance Management System
OSD/NC	Offshore Services Department/New Construction
PFEER	Prevention of Fire, Explosion and Emergency Response Regulations
SCE	Safety Critical Element
SCR	Safety Case Regulations
SMS	Safety Management System
VCS	Verification Control Sheet

Reference Documents

[1] Department of Energy – The Public inquiry into the Piper Alpha disaster (Cullen Report), HMSO 1990 ISBN 0 10 1131102 X

[2] SCR The Offshore Installations (Safety Case) Regulations 1992, SI 1992 No 2885

[3] A Guide to The Offshore Installations (Safety Case) Regulations 1992, HMSO Publication L30, ISBN 0-11-882055-9

[4] Safety at Work – Third Edition, edited by John Ridley – Butterworth Heinemann ISBN 0 7506 1018 2

[5] A guide to the integrity, workplace environment and miscellaneous aspects of the Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996'

Reference Number: (L85) ISBN 0 7176 1164 7

[6] 'A guide to the well aspects of the Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996'

Reference Number: (L84) ISBN 0 7176 1194 9

[7] 'A guide to the installation verification and miscellaneous aspects of amendments by the Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996 to the Offshore Installations (Safety Case) Regulations 1992'

Reference Number: (L83) ISBN 0 7176 1193 0

[8] UK Offshore Regulations, LRTA Paper No. 6, Session 1991-92, P. Tindall

[9] Performance Standards and Written Schemes – Recent Experience from the UK Offshore Industry, LRTA Paper No. 3, Session 1995-96, J. R. Lane and M. C. Jones

Typical Verification Scheme Matrix

(Note: references under 'Verification Activity' provide details of appropriate alliance member)

Underpinning Regulations & Rules					Definition		Verification Activity					
PSR	PFEER	DCR	CLASS	FLAG	VCS No.	SAFETY CRITICAL ELEMENTS	DESIGN	MANUF.	CONV/ FAB.	ONSHORE COMMS.	OFFSHORE INST.	OFFSHORE HUC
					1	Wellheads						
✓		✓	✓		3	Subsea	Vi	Vi	Vi	Vi	Vi	Vi
					3.1	Risers						
					3.2	Flowlines						
					3.3	Gas Exp SSIV						
		✓	✓		7.1	Mooring System	Viii	Viii	Viii	Vi	Vi	Vi
		✓	✓		7.2	Fluid Transfer System	Viii	Viii	Viii	Vi	Vi	Vi
		✓			10	Oil Separation	Vi	Vi	Vi	Vi		Vi
		✓			15	Crude Oil Metering	Vii	Vii	Vii	Vi		
		✓			17	Crude Oil Export	Vii	Vii	Vii	Vi		Vi
		✓			20	Gas Compression	Vi	Vi	Vi	Vi		Vi
		✓			22	Gas Dehydration	Vi	Vi	Vi	Vi		Vi
		✓			25	Gas Metering	Vi	Vi	Vi	Vi		Vi
		✓			27	Gas Export	Vi	Vi	Vi	Vi	Vi	Vi
		✓			50	HP Flare	Vi	Vi	Vi	Vi		Vi
		✓			51	LP Flare	Vi	Vi	Vi	Vi		Vi
		✓			52	Fuel Gas	Vi & Vii	Vi & Vii	Vi & Vii	Vi		Vi
		✓			53	Helicopter Fuel	Vii	Vii	Vii	Vi		
		✓	✓		54/M26	Diesel Fuel	Vi & Vii	Vi & Vii	Vi & Vii	Vi		
		✓	✓		60	Hazardous Open Drains	Vi	Vi	Vi	Vi		Vi
		✓			73	Chemical Injection (Methanol)	Vi	Vi	Vi	Vi		Vi
✓		✓			74	Subsea Controls	Vi	Vi	Vi	Vi	Vi	Vi
		✓			79	Mechanical Handling	Vii	Vii	Vii	Vi		Vi
		✓	✓		11	Process Deck Topsides Structure	Vi	Vi	Vi			
		✓	✓	✓	M2	Hull Structure	Vii		Vii		Vi	Vi
		✓	✓		M3	Sea Valves	Vii	Vii	Vii	Vi		
		✓	✓		M16	Ballast System	Vii		Vii	Vi		Vi
		✓	✓		M17	Cargo System (Crude Oil Storage)	Vii	Vii	Vii	Vi		Vi
		✓	✓	✓	M18	Inert Gas	Vii		Vii	Vi		Vi
		✓	✓		M28	Boiler Plant	Vii	Vii	Vii	Vi		

Annex 2

Lloyd's Register

Project Development
Verification Control Sheet

Duty Holder :

VCS No :

Revision : **Date:**

LR Contract No :

LR Ref: OS/

Safety Critical Element (SCE) Identification :

SCE Description :

Performance Standards/ Acceptance Criteria :

Verification Procedures :

Verification Activities :

Verification Contribution to:

PFEER	☐	Class	☐
PSR	☐	Flag	☐
DCR Wells Examination	☐	Other	☐

Approved on Issue:

Name:
Date:
LR Verification Manager:

Feedback:

Design Review Completion: ☐
Survey Complete: ☐

Completion:

Name:
Date:
Signature:

This document forms part of a Verification Scheme as prescribed by SCR SI 2885 as amended by DCR SI 913 and implemented on behalf of <Client> for the <Project> development. Agreed terms and conditions as per above referenced contract.

Verification Scheme

Verification Control Sheets

VWI 10

Sheet 1 of 1

Lloyd's Register	**TYPICAL FPSO PROJECT** **VERIFICATION SCHEME** **VERIFICATION WORK INSTRUCTION**
SYSTEM IDENTIFICATION **System 10 - OIL SEPARATION**	Project work instruction:- QS 04-20 DR/
Examination of Design of Safety Critical System	Verification Control Sheet:- VCS 10

The examination of design to verify suitability for compliance to the project integrated design basis/performance standard will include review of the following aspects:

- Requisition for consistency with Integrated Design Basis
- Piping material, fittings and components for service fluids, temperatures and fire, during normal and upset conditions
- System components for inventory pressure containment during normal and upset conditions
- System induced and external loads to include process surge, ship motions, thermal, relief/blowdown, snow/ice accretion, mechanical load/damage and blast overpressure
- Piping support philosophy/specification
- System inventory disposal (relief) arrangements to include relief valve location, capacity and availability
- Fabricated system strength test and NDE level proposals
- Hydrocarbon/hazardous fluid storage tank/containment including selection of materials, design code and strength test

- System protection arrangements such as:
  - Remote valve closure
  - Remote pump stops
  - Electric heater temperature cut out
  - Hydrocarbon or hazardous fluid migration into non-hazardous system
  - Flame arresting
  - Drains trap/seal arrangement

- System layout:
  - cross connection of hazardous/non-hazardous e.g. drains disposal system
  - Reverse flow conditions
- - Relief vent location

Prepared by :	Description	Issue 1
Authorised by :	Issued for Implementation	Date 11/12/96

Terms and Conditions specified in Contract No. <...> is applicable.

Annex 3

CHRONOLOGY OF UK VERIFICATION AND CLASS ACCEPTANCE

COMPLETION PHASE:	REGULATION		
	All Installations Verification	FPSOs & MODUs Class	FPSOs & MODUs Statutory
Project Concept Stage			
	←	Conceptual Design Review	→
Deliverable	Conceptual	Design Appraisal	Statement
Project Start Up			
	Identify Safety Critical Elements (SCEs) Develop Verification Scheme and Issue Verification Control Sheets (VCS) (ongoing) ↓	Clarify Class and Class Notations	Clarify Flag Requirements and Statutory Certificates
Deliverable	Statement / Comment on list of SCEs		Agreement by LR to Issue Statutory Certficates
Detail Design			
	Detail Design Appraisal of SCEs as per VCS	Detail Design Appraisal and Rule Compliance	Statutory Code Compliance Approval
Deliverable	Design Verification Statement	Approved Drawings as per Class Rules	Approved Drawings and Documentation
Equipment and Machinery Procurement			
	Verify DA and Construction of SCEs as per VCS	Class Surveys and Certification	
Deliverable	Verification Statement	Equipment and machinery Certificates	

Typical Chronology

CHRONOLOGY OF UK VERIFICATION AND CLASS ACCEPTANCE

COMPLETION PHASE:	REGULATION		
	All Installations Verification	FPSOs & MODUs Class	FPSOs & MODUs Statutory
Construction Hull and Machinery			
	Verify Construction of SCEs as per VCS	Class Surveys	Statutory Surveys
Deliverable	Construction Verification Statement	1st Entry Class Reports to LR HQ	
Prior to Sail-Away/Tow Out			
Deliverable	Sail-Away Verification Statement	Interim Class Certificate with Outstanding Class Items	Short Term Statutory Certificates or Obtain MSA Exemptions
Installation and Commissioning			
Deliverable Prior to First Oil	Hook-Up and Commissioning VCS	Class Installation Report to LR HQ. All Outstanding Class Items Closed Out	
Prior to First Oil			
Deliverable	Statement that Verification is Complete		
Final Deliverables	Full Verification Report	Class Certificate Issued by LR HQ	Full Term Statutory Certificates as Applicable

Typical Chronology

LR *Technical Association*

Passenger Ship Safety – A Review of Convention Requirements and LR Survey Procedures

by S. W. Hawkins, C. M. Magill and J. Polderman

Lloyd's Register

Paper No 7
Session 1996–1997

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Written contributions to the discussion of this paper are invited from members of the Lloyd's Register Technical Association. To ensure inclusion in the discussion paper, the contributions should be received by the Hon. Secretary in London not later than 31st July 1997.

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Passenger Ship Safety – A Review of Convention Requirements and LR Survey Procedures

by S. W. Hawkins, C. M. Magill and J. Polderman



Stuart Hawkins spent six years at sea as a deck officer with Sugar Line before attending the University of Southampton to obtain a degree in Naval Architecture. He joined Lloyd's Register in 1987 and has undertaken survey duties in Liverpool, Headquarters, Livorno and Trieste where he has been resident at the Monfalcone Shipyard of Fincantieri S.p.A. since 1989. He has primarily been involved in the construction of passenger ships. In 1996 he was promoted to Senior Surveyor.



Mike Magill had a student apprenticeship at Harland and Wolff Ltd. and the University of Newcastle upon Tyne, followed by a period at Stone Manganese Marine Ltd. working on the development of controllable pitch propellers and with the Royal National Lifeboat Institution working on the development of the fast offshore lifeboat fleet. He joined Lloyd's Register in July 1975 and initially dealt with marine new construction of various ship types, offshore installations and industrial services contracts whilst based in Glasgow. He was transferred to HQ in 1980 to deal with fire and safety aspects of the complete spectrum of Lloyd's Register's business activities. He became a Senior Surveyor in 1983 and promoted Principal Surveyor for Statutory Computational Services in 1988 with responsibility for stability and tonnage computation. In 1993 he was promoted to Senior Principal Surveyor for Statutory Services.



Jack Polderman had an apprenticeship at Royal Schelde Shipyard and studied for a Naval Architecture degree at the Higher Technical College, Dordect. Whilst with Royal Schelde he was promoted to Manager of Ship New Construction before joining Lloyd's Register in 1970 at Rotterdam. He was transferred to the United States in 1978 to work in the Mobile Office, became surveyor-in-charge of New Orleans in 1985, Principal Ship Surveyor at Miami in 1990 with responsibility for passenger ship affairs and promoted Senior Principal Surveyor for the USA in 1996.

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Part I – Pre-Contract Service, Design Appraisal and Plan Approval
Part II – New Construction, the Initial Passenger Ship Safety Survey
Part III – Existing Ships, the Passenger Ship Safety Renewal Survey

Part I

Pre-Contract Service, Design Appraisal and Plan Approval

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1 Pre-Contract Service
2 Newbuilding Design Appraisal and Approval

Part II

New Construction, the Initial Passenger Ship Safety Survey

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2 Steel Construction
3 Watertight Integrity
4 Lifesaving Appliances
5 Fire Protection
6 Other Statutory Items
7 UCSG Visit
8 Passenger Ship Safety Survey
9 Final Comments

Part III

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2 Preparation for the survey
3 The survey
4 Report of Passenger Ship Safety Survey
Form 2112 R (Report)
5 Survey checklist. Form 2112 (Checklist)

Appendix A – Schedule and Remarks of the Passenger Ship Safety Survey
Appendix B – Masters Questionnaire

Introduction

Lloyd's Register has a long history of involvement with passenger ships which extends back to the earliest years of the Register Society after its formation in 1760. In the earliest years of the Society all ships carried a number of passengers although their main function was to carry cargo. During the mid 1800's, when one of the major migrations of the European population to the Americas began in earnest, passenger ships began to be constructed as a generic type. It was at this time also that paddle steamers began to be introduced and power gradually took over from sail as the main method of propulsion. Up until the 1960's passenger ships had the same role as the present day airliner for the general transport of people around the world and, similarly, carried limited amounts of cargo which needed rapid movement or was of a valuable nature, such as mail and gold bullion or gem stones.

From the 1960's onward, when air fares began to become reasonably priced, the liner trade of passenger ships rapidly declined and many famous named ships were broken up, laid-up for other uses such as floating hotels or, in a few instances, converted to cruise ships for the more wealthy tourist of that time. Cruising is now enjoying ever increasing popularity, a factor which is greatly influenced by the reduced cost of cruises and the improved general wealth of Americans and Europeans who form the bulk of today's passengers.

Classification rules for passenger ships have been in existence from the time of wood construction, through composite wood and iron, rivetted iron and finally steel. However, Lloyd's Register's involvement in the passenger ship safety aspects of the SOLAS Conventions did not begin until 1950 when delegation by the open registers of Liberia and Panama began. Since the entry into force of the SOLAS 1948, 1960 and 1974 Conventions, some 40 national Administrations have authorised Lloyd's Register to undertake the plan approval and survey of passenger ships for the issue of the Passenger Ship Safety Certificate.

LR has established itself in a pre-eminent position in the classification and certification of passenger ships where, in terms of gross tonnage, LR classes 50% of the world's cruise ships currently in service and LR class is specified for 61% of the tonnage under construction or on order. Figure I.2 summarises the classification of the world fleet of passenger ships of 5000 gross tons and above while Figure I.3 indicates the LR class passenger ships from 1950 onwards in terms of both ship numbers and gross tonnage.



Figure I.1
Carnival Destiny, currently the largest passenger ship in the world

Achievement of this position has been established through the use of a co-ordinating team of specialist surveyors in Headquarters to deal with pre-contract advice and guidance to Owners and their consultants, design appraisal and plan approval of all classification and statutory aspects when submitted by the Owner's selected shipbuilder and visits to the building yard to provide specialist advice and back-up to the local surveyors authorised to deal with initial passenger ship safety surveys. After delivery, the maintenance of classification and annual renewal of the passenger ship safety certificate is dealt with by strategically located surveyors who are specifically authorised for this type of work. The co-ordinating group in HQ is CSD Statutory Approval Services/Passenger Ship Safety but it is the dedication of the whole team who are involved from comment on conceptual designs through to the maintenance of certification in service that has enabled LR to have such a pre-eminent position in the passenger cruise ship market.

There are three distinct phases in the progress of a passenger ship from an Owners conceptual idea through to successful service and it is for this reason that this paper has three authors, each from a different geographical location where the work is primarily carried out. Thus, the paper is divided into three parts which address the principal functions of Lloyd's Register in each phase.

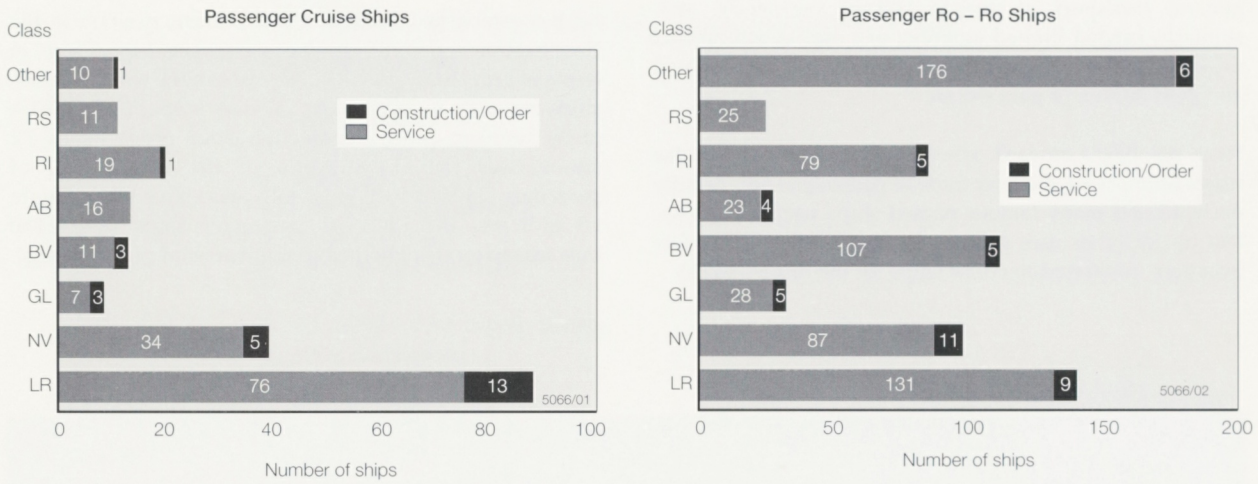


Figure I.2
World fleet statistics by class

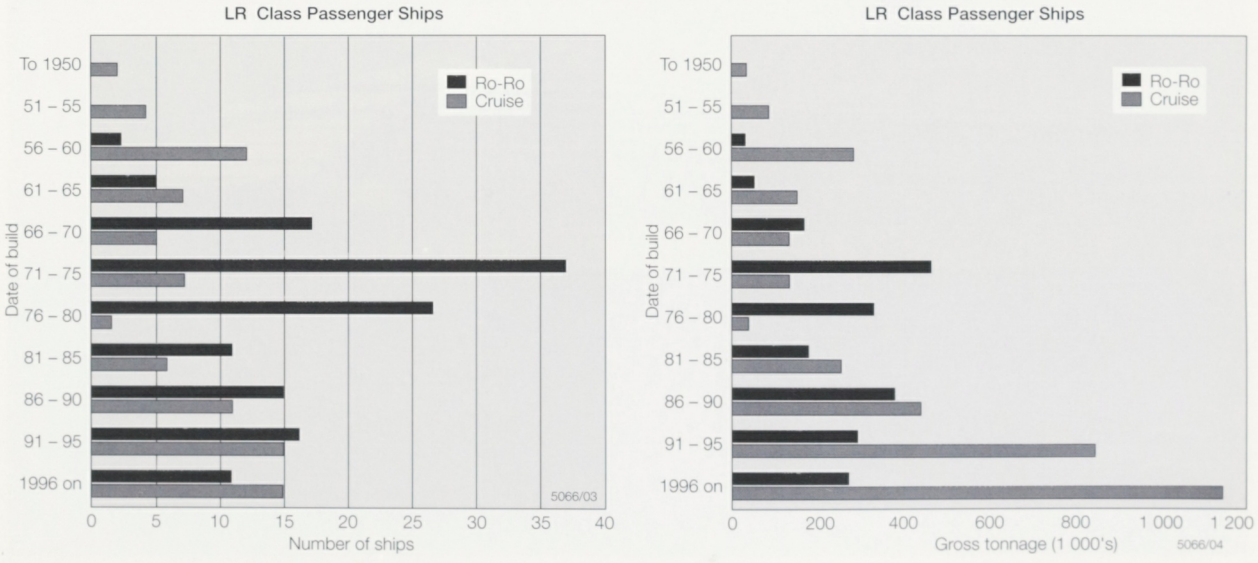


Figure I.3
LR class fleet statistics

Part I

Pre-Contract Service, Design Appraisal and Plan Approval

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- **2.3** Electrical Engineering
- **2.4** Control Engineering
- **2.5** Other Optional Classification Services
- **2.6** Passenger Ship Safety Certificate Aspects
  - **2.6.1** Historical Development of the Requirements
  - **2.6.2** Basic Requirements of the 1992 and 1994 Amendments
- **2.7** United States Coast Guard Requirements
- **2.8** Final Comments

1 Pre-Contract Service

Shipbuilders, with whom LR establishes contracts to provide classification and statutory services, very often have a significant influence on the choice of classification to be offered to the owner of a cargo ship. For passenger ships the reverse is usually the case. The high capital cost of passenger cruise ships and the much greater involvement of the classification society during the life of the vessel tend to be factors which mean that prospective Owners will specify the preferred society.

There has already been significant expansion in the number of cruise ships and berths available and, as a consequence, the cruise industry is becoming increasingly competitive. Each cruise line is offering ever more innovative programmes such as theme cruises, new itineraries, family cruises, etc., and also upgrading their product with more spacious ships, better food and entertainment and public space arrangements to rival the best land based hotels and shopping centres. These latter features often involve aspects which require special consideration of the ship structure, fire safety arrangements or power and manoeuvring capabilities. Since it is the Owners perceived need to have such features in order to attract passengers, it is usually the Owner who will work with a classification society which provides a pre-contract service to verify the viability of the concept design and, later, will specify that society in the contract to build the ship.

However, should the class be left open to the Builders choice, then Lloyd's Register would offer the same pre-contract service to the builder. As a result of the general reduction of naval defence budgets around the world, many shipyards which were normally associated with naval construction are now searching for orders in the merchant ship sector. Lloyd's Register has also been involved in briefing such yards on the changes and adaptation of different technologies which will be necessary for them to be successful in building merchant ships, particularly if it is the passenger ship sector they have in mind.

Pre-contract work is generally carried out by HQ specialists in ship structures, fire and lifesaving appliances and propulsion systems but may also include other aspects of particular relevance to the Owner and local surveyors in the various parts of the world to which they are required to travel.

2 Newbuilding Design Appraisal and Approval

When LR class is selected, the co-ordinating team in HQ will ensure that classification and statutory certification proceeds smoothly and in a cost effective manner. This will involve liaising with plan approval groups dealing with ship structures, machinery, pumping and piping, electrical engineering and control engineering, both in HQ and other plan approval centres authorised for these aspects. The primary subject of this paper is the safety surveys of passenger ships, but it will become clear that, while the stability, fire and LSA aspects are dominant in the volume of work to be carried out, the passenger ship safety certificate is based on compliance with the hull and engineering aspects of the classification Rules. Since the whole emphasis of LR's approach to passenger ships is on co-ordinated team work, it would be inappropriate not to give some information about classification aspects.

2.1 Hull Structure

The standards for hull construction given in the Rules reflects the extensive experience gained through LR's involvement with passenger ships over many decades.

The structural configuration of a cruise ship is usually determined firstly by the location of the main fire zone bulkheads which are themselves a function of the cabin width, number of cabins required on each deck and the space limitation of fire zone length. Secondly, the structural configuration below the bulkhead deck will be determined by the location of watertight bulkheads which are needed to comply with the damage stability criteria. Additionally, all or some of these watertight bulkheads will have to be in line with the main fire zone bulkheads. The third influence is the location of lifeboats and liferafts which must now be located to minimise the lowering distance to the water. This structural concept requires a large recess just above the ship's mid-depth and thus reduces the structural continuity and effectiveness of the shell. In addition to these factors, shell openings for the embarkation of passengers, crew and supplies can unfortunately be needed in locations which compromise the structural efficiency of the hull. Because of the desire to have a "hotel room" feeling in the cabins, large windows with very small corner radii are usually proposed.

For all these reasons it is normal to employ advanced finite element analysis techniques to assist both the Builders and ship structures plan approval staff in achieving a satisfactory and efficient structural arrangement. The HQ team in Construction Services Department has unrivalled experience in this area.

2.2 Machinery, Pumping and Piping

In addition to the prime mover, design appraisal includes the usual auxiliary units such as boilers, FW generators and auxiliary engines, together with pumps and piping serving the machinery spaces, ballast spaces, accommodation services etc. The machinery spaces will also be considered for attended/unattended operation.

So far as the choice of prime mover is concerned diesel engines have, for a number of years, completely monopolised this sector of the marine market.

The simplest arrangements for propulsion service are either direct drive or those incorporating reduction gear units. However, the alternative to direct and geared drive propulsion is diesel-electric power which has many advantages because the generators can supply main propulsion and hotel load and may be flexibly mounted to reduce both noise and vibration. This is the method used in most cruise ships today.

For multiple screw vessels having shaft supports outboard of the hull, the arrangements are examined to ensure the shafting system is free from harmful lateral vibrations induced by propeller excitation. Particular attention is paid to the screwshaft design and the propeller connection. Shaft couplings transmitting torque by interface friction or pure shear are calculated and acceptance is based on any adequate safety factor against slip or yield. Propellers are increasingly being designed with high skew angles to reduce vibration and finite or boundary element analyses are used to assess strength.

LR's Rules for steering gears incorporate the current Amendments to SOLAS. Steering systems are examined on the basis that a single failure will not result in loss of steering capability. Rudder actuators must be constructed in accordance with the requirements for Class 1 pressure vessels and are examined accordingly.

Diagrammatic plans of the various systems within the machinery and boiler spaces and detailed plans of individual items such as pumps, valves, safety valves, etc. are examined for compliance with LR's Rules which are in line with the latest Amendments to SOLAS 1974.

2.3 Electrical Engineering

Plans are examined to ensure that the electrical auxiliary services necessary for maintaining the ships in normal operational and habitable conditions can be ensured without resource to the emergency source of electrical power, electrical services essential for the safety of the ship and of personnel are maintained under various emergency conditions and that the safety of passengers, crew and ship from electrical hazards will be ensured.

Design appraisal of the electrical power generation and distribution system includes:

- analysis of the schedule of normal operating loads on the main and emergency systems for the operating conditions expected,
- verifying the fault current analysis and ensuring the installed circuit breakers and/or fuses are adequately rated for the fault level at their point of installation,
- ensuring that the installation is protected against accidental currents, including short circuit and that the electrical protective devices provide complete

and co-ordinated protection,
- review the electric cables with respect to their suitability for the system voltage and for the current of the connected load,
- ensuring that no single fault or loss of an electrical supply will cause the loss of the main electrical power plant or, where fitted, the electric propulsion plant.

In addition, appraisal is carried out on the following crew and passenger safety systems for compliance with the Society's Rules and SOLAS, taking into account all relevant amendments:
- Emergency lighting, including transitional and supplementary systems
- Fire detection, alarm and extinction systems
- Public address system
- General alarm
- Watertight doors
- Fire doors

2.4 Control Engineering

Control engineering arrangements are considered for the intended machinery space operational mode: attended, unattended or centralised control.

Control schematics, handbooks, sensor lists and test schedules are reviewed for safety shutdown, monitoring and alarm, and remote and automatic control arrangements of all essential systems together with items such as bridge propulsion control, fire and bilge level detection, machinery control room arrangements etc.

Where programmable electronic systems (PES) are employed, LR review:
- system requirements specification
- hardware configuration
- graphic representation of sequential function elements eg. flow charts, ladder diagrams
- self monitoring techniques
- communication protocol and data transfer rates.

Software quality plans for documented software development methodology are also reviewed to ensure all software module interfaces are defined, processor power and memory capacity is adequate and test procedures and acceptance criteria are defined.

2.5 Other Optional Classification Services

Bridge ergonomics and the arrangement of the navigational equipment are vital factors for easing the work load of the navigational officer of the watch.

When requested by the Owner, LR can assess these arrangements and the bridge equipment fitted against the Provisional Rules for Shipborne Navigational Equipment and assign the appropriate "Lloyd's Navigation Certificate" NAV class notation, the highest being NAV1 for periodic one-man watch. In the assessment for this notation a Failure Mode and Effect Analysis (FMEA) is carried out to ensure the reliability of navigation functions and to see that no fault affecting safety can go undetected.

A further development in system integration is to bring all active fire detection and fire protection arrangements to a single control centre which could be on the bridge or at an independent fire control centre.

Shipowners and port authorities are increasingly interested in assessing, for example, if larger or new types of ships can be safely manoeuvred in ports which, until now, only received smaller or more manoeuvrable ships. Port authorities are also realising the need to evaluate port developments with regard to safe manoeuvring of the expanded ship types.

LR has undertaken extensive research in the prediction of ship manoeuvring behaviour and two major computer programs have been developed. One program uses input that describes the geometry of a ship, its rudder and propeller, the shape of the stern and the available power to produce estimates for resistance, propulsion and hydrodynamic manoeuvring coefficients. The second program employs this data to simulate the ship's dynamic response of surge, sway, yaw, roll and propeller revolutions to given commands of engine telegraph and rudder.

2.6 Passenger Ship Safety Certificate Aspects

The foregoing are the foundation on which appraisal by the HQ passenger ship safety specialists is carried out. Intact and damage stability assessment has been dealt with in LRTA Paper No. 7 Session 1990-91 and is not discussed here. However, the fire protection, detection and extinction and lifesaving appliances aspects have all been subject to regulation amendments by IMO which have not been previously discussed in an LRTA paper.

These subjects are addressed in separate chapters of SOLAS but are so interlinked that any discussion about passenger ship safety must encompass them as a whole. The Convention takes cognisance of the need to contain any outbreak of fire in the space where it originates by the provision of structural fire division boundaries; to detect the outbreak of fire as early as possible by the provision of detection systems appropriate to the fire risk; provide fixed and portable fire-fighting equipment of the right type and sufficient capacity to extinguish possible fires; provide protected escape routes for passengers and safe access for fire-fighting teams; and, when all else fails, suitable lifesaving appliances to enable safe and orderly evacuation of the ship. This is a complex safety process and requires specialist co-ordination of many separate disciplines (electrical, piping ventilation, etc.) to ensure that the intended level of safety is not compromised.

The words 'safe and orderly evacuation' imply the intent of the level of safety to be achieved but it should be remembered that people panic in their own culture and language and the consequences of this should also be taken into account in the overall safety philosophy for the ship.

Fire safety aspects and lifesaving appliances are part of the outfitting and equipment of a ship. For passenger vessels this comprises the bulk of the work and is also the area in

which most innovations in design and technology are likely to be applied. Thus this part of the construction requires the greatest co-operation between the Owners interior designer or concept consultant, the Builders detail designers, the Builder's component suppliers and the classification society in order that the final product satisfies the original concept whilst remaining within the safety provisions of the Convention. It is estimated that about 75% of the total cost of a passenger cruise ship is in the outfit and equipment. Since this will all be bought-in cost it is essential that the greatest management care be exercised in this area. Suppliers will be familiar with their own individual component but will not be familiar with the ship's design concept or fabrication method. Therefore optimum results can only be achieved when the Builder does not delegate an engineering problem but ensures that component suppliers work together to solve problems and suggest improvements in economy. In this way, for example, a standard bathroom module can be created. This can then be integrated into a standard cabin module, which will then plug into a standard construction block for erection at the ship. All these functions can be carried out in the protected environment of a workshop thus creating the opportunity for high quality at lowest cost. Builders have estimated that rectification of defects at the ship cost ten times more than at assembly in a workshop and similarly the elimination of component defects at assembly in a workshop costs ten times more than at the original manufacturing base. If there are 1000 cabins involved, then a little simple arithmetic will indicate the possible scale of financial disaster if total co-operation and commitment is not obtained from all parties at all times.

2.6.1 Historical Development of the Requirements

The regulations are contained successively in the 1929, 1948, 1960 and 1974 International Conventions for the Safety of Life at Sea (SOLAS), the Protocol of 1978 relating to SOLAS 1974 and the subsequent Amendments to SOLAS 1974 .

All of this legislation, with the exception of the 1929 and 1948 conventions, was introduced by IMO after development by its Sub-Committee on Fire Protection. This Sub-Committee meets formally for only one week each year, therefore, the speed of development of new regulations is limited. Whilst over the years it has been obvious that new regulations were necessary in many specific respects, priority had to be given to the ship types and hazard risks where the greatest number of explosions and serious fires were occurring at the particular time. Fire casualties are emotive and receive widespread coverage in the news media, thus pressure for changes in the regulations often follow such an event. The number of lives lost and, latterly, the effect on the environment are factors which exacerbate such emotions.

The first convention in 1929 was the result of the tragic loss of the "TITANIC". Since that disaster was the result of a collision with an iceberg which caused extensive flooding and many lives were lost due to an inadequate provision of lifeboat capacity, the 1929 convention is mainly concerned with sub-division and lifesaving appliances. It contains little relating to fire safety.

It was the 1948 Convention which introduced the International Passenger Ship Safety Certificate and the Cargo Ship Safety Equipment and Safety Radio Certificates. This heralded LR's involvement in the survey and certification of ships in those respects on behalf of several governments. The Passenger Ship Safety Certificate concerns, among other things, requirements for structural fire protection, fire detection and fire extinction and provision of lifesaving appliances.

The 1960 Convention slightly improved the standards of the 1948 Convention, otherwise there was little significant change. Similarly, the 1974 Convention closely resembles SOLAS 1960 but includes all the Resolutions adopted by IMO in the intervening period. Perhaps more importantly, it also adopted a new procedure which requires that amendments to the Convention automatically come into effect at the end of two years, or another period which is not less than one year at the discretion of the IMO Maritime Safety Committee (MSC), unless either more than one third of the Contracting Governments, or Contracting Governments whose combined fleets constitute not less than 50 per cent of the world merchant fleet, register an objection. This means that it will no longer be necessary to wait for years for a convention, or amendments to a convention, to come into force. It may be remembered that the 1948 Convention took four years to enter into force, the 1960 Convention five years and the 1974 Convention six years. Among the resolutions which were incorporated into the 1974 Convention were improvements in the fire safety requirements for passenger ships, including existing ships carrying more than 36 passengers. It was at this time that, due to the Fire Safety Requirements having become so voluminous, a separate Chapter II-2 was created.

Further updating of the fire safety aspects was made in the 1981 Amendments to SOLAS 1974 and these have remained in force until the major revision of the 1992 Amendments, which entered into force in October, 1994 and forms the basis for most of the content of this paper.

It is worth mentioning that up until 1994 the three methods of fire safety protection addressed by the successive Conventions were based on the practices of the three former major liner service Administrations, USA, UK and France. The United States practice was to require essentially non-combustible construction and limited fire detection systems; the UK practice was to require non-combustible construction in certain areas and permit the use of combustible materials in other areas provided that fire detection and extinction (sprinkler) systems were fitted; the French practice was similar to that of the UK but permitted greater use of combustible construction provided more extensive use of detection and extinction systems was employed.

The 1992 Amendments now have only one standard for structural fire protection and require detection and extinction systems fitted throughout the ship. Since such standards are also to be retrospectively applied to existing ships by scheduled dates, it is not envisaged that these requirements are likely to be changed for some time to come except perhaps for minor amendments found to be necessary during their use.

2.6.2 Basic Requirements of the 1992 and 1994 Amendments

In order to confine any outbreak of fire to proportions which will provide a reasonable possibility of achieving its extinction and, furthermore, to facilitate the escape of the passengers and crew from their accommodation at all levels to the embarkation deck, the hull, superstructure and deckhouses are subdivided into main vertical fire zones by bulkheads spaced nor more than 48 metres apart. These bulkheads must extend from deck to deck and to the shell or other steel boundaries. They should generally be in the same vertical line from the tank top up to the uppermost deck. Below the level of the bulkhead deck, the watertight sub-division bulkheads may also serve as main fire zone bulkheads and above that level the main fire zone bulkheads should, as far as practicable, follow the same vertical line. Where this is impracticable the bulkhead may be stepped, although such steps and recesses should be kept to a minimum.

Examination of the fire division insulation standards of the 1981 Amendments will show that there were two standards to be applied, one for main fire zone bulkheads and decks and the other for adjacent spaces within the main fire zones. The standard now applied is that main fire zone bulkheads and decks are to be A-60 class irrespective of the type of space on either side, with the exception of sanitary spaces or open decks. The fire integrity and insulation values of the boundaries of adjacent spaces within the main zones are now given in Regulation 26, tables 26.1 and 26.2. The integrity standard and insulation value are in each case dependent on the nature of the fire risk in each of the adjacent spaces. A bulkhead, for example, separating two toilet spaces where the fire risk is low would not require as high a standard of insulation as one separating a fire control station from an engine room. It will be noted from these tables that the alternative standards for sprinklered and non-sprinklered spaces has been removed since such protection is now mandatory.

The upgrading of insulating standards in these tables above the levels prescribed by the 1981 Amendments are estimated to add about 400 tons to the lightship weight of a medium sized passenger cruise vessel, so their effect is significant. However, a greater effect on the design and layout of cruise ships has been caused by a change to Regulation 28 concerning means of escape which states: *"A corridor, lobby, or part of a corridor from which there is only one route of escape shall be prohibited"*.

When considering design changes as a result of the 1990 Amendments concerning stability and the use of partial bulkheads to limit the extent of flooding on and above the bulkhead deck, the centreline corridor arrangement with dead end spurs leading to cabins appeared to offer a readily compliant layout with maximum use of the space available. However, this is now prohibited and arrangements using port and starboard longitudinal corridors with transverse interconnection seems to be the norm, even though there may be associated damage stability aspects to consider.

A further change in Regulation 28 states:

5. *At least one of the means of escape required by paragraphs 1.1 and 1.2 shall consist of a readily accessible enclosed stairway, which shall provide continuous fire shelter from the level of its origin to the appropriate lifeboat and liferaft embarkation decks, or to the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by way of external open stairways and passageways shall be provided and shall have emergency lighting in accordance with Regulation III/11.5 and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck shall have fire integrity, including insulation values, in accordance with the tables in Regulation II.2/26. The widths, number and continuity of escapes shall be as follows:*

5.1 *Stairways shall not be less than 900mm in clear width. Stairways shall be fitted with handrails on each side. The minimum clear width of stairways shall be increased by 10mm for every one person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900mm shall be 1,800mm. The total number of persons to be evacuated by such stairways shall be assumed to be two thirds of the crew and the total number of passengers in the areas served by such stairways. The width of the stairways shall conform to standards not inferior to those adopted by the Organisation.*

5.2 *All stairways sized for more than 90 persons shall be aligned fore and aft.*

5.3 *Doorways and corridors and intermediate landings included in means of escape shall be sized in the same manner as stairways.*

5.4 *Stairways shall not exceed 3.5m in vertical rise without the provision of a landing and shall not have an angle of inclination greater than 45°.*

5.5 *Landings at each deck level shall be not less than $2m^2$ in area and shall increase by $1m^2$ for every 10 persons provided for in excess of 20 persons but need not exceed $16m^2$, except for those landings servicing public spaces having direct access onto the stairway enclosure.*

Whilst prescriptive rules have existed for some time in the national regulations of the US and UK with respect to stairway widths, this is the first time that they have been defined in the Convention. The total enclosure of the stairway from the lowest level up to the embarkation deck is also new and is associated with the provision of a separate ventilation system for the enclosures forming escape routes such that protection against smoke inhalation is provided. Of the deaths that result from fires, the greater majority are because of inhalation of the toxic products of combustion rather than exposure to flame. Psychologically, the sight or smell of smoke can induce panic, even when it appears in an area as yet unaffected by heat or flames. This panic need not be expected to be confined to the passengers, the non-marine crew who have not had fire fighting training and experience could be similarly affected.

Recognising the physiological effects of smoke which incapacitates by is powerful irritant action on the eyes, nose, throat and lungs and that initially it will spread across the upper part of any space in which it occurs, a new requirement for low level marking of escape routes has

been introduced. This states:
"In addition to the emergency lighting required by regulations II-1/42 and III/11.5, the means of escape, including stairways and exits, shall be marked by lighting or photoluminescent strip indicators placed not more than 0.3m above the deck at all points of the escape route including angles and intersections. The marking must enable passengers to identify all the routes of escape and readily identify the escape exits. If electric illumination is used, it shall be supplied by the emergency source of power and it shall be so arranged that the failure of any single light or cut in a lighting strip will not result in the marking being ineffective. Additionally, all escape route signs and fire equipment location marking shall be of photoluminescent material or marked by lighting. The Administration shall ensure that such lighting or photoluminescent equipment has been evaluated, tested and applied in accordance with the guidelines developed by the Organisation".

An example of such marking systems will be familiar to those travelling regularly in airlines and proposals for marine systems are presently being evaluated.

Earlier reference has been made to the innovative impact that the passenger ship industry has had on design and it is in the area of structural fire protection that one innovation has had most impact. This is the atrium, or variations of it, which is such a feature of the ships now entering service.

Lloyd's Register's first experience of events leading to the grand features of today was in finding a solution to a concept designer's wish to create a "shopping mall" where the shops on each side had glass fronts to continuously display the goods. The fire protection standard required was B-15 class which meant a division which could withstand the half hour standard fire test and prevent a rise in temperature on the non-exposed side of not more than 180°C for a period of 15 minutes. The technology used to provide the solution was imported from the offshore oil industry where small sized windows of A-60 standard had been developed to provide protection of essential control stations from the effects of a wellhead fire. Such windows were triple glazed, the outer being toughened glass, to provide the structural integrity, the middle being a laminate of glass and a specially treated polycarbonate which occludes when exposed to heat and gives protection against the radiant effects of fire and the inner of normal glass with a vacuum between it and the middle layer to provide protection from heat conduction. However, even though the windows were small, they were expensive!

Recognising that a B-15 class shop front would be subject to less onerous fire criteria, much larger panels were tested and, after a few failures of the supporting frame, a system was developed which could be certified for use in such locations. Having achieved this first step, the concept of an internal atrium soon followed since, not only is the arrangement visually attractive, it is possible to provide windows in cabins overlooking the atrium and thus obtain an increased income from the larger number of "premium cabins" with a view.



Figure I.4(a)
Low location lighting in corridor



Figure I.4(b)
Low location lighting in stairs

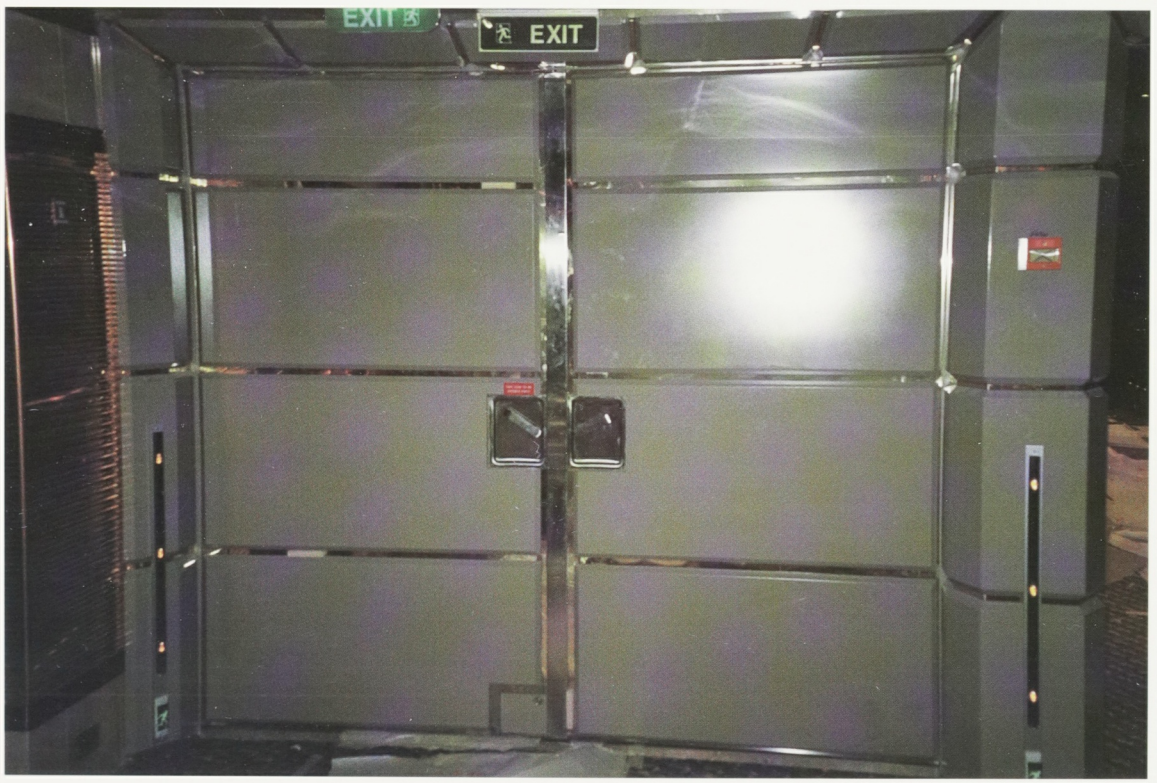


Figure I.4(c)
Low location lighting at fire door

Structural fire protection is the foundation of the onboard safety system and it is essential that it is not compromised by the other necessary work that must be done to provide services such as electrical, plumbing, ventilation, etc. All penetrations of fire rated divisions must be made in such a way as to prevent the passage of smoke and flame and to prevent thermal heat-bridging. Since all such details will eventually be covered by aesthetic finishes and will not readily be seen again during many years service, it is vital that the quality culture of the workforce is first class in this area. It is also the area in which the classification surveyors will spend an enormous amount of time ensuring that this is the case.

Having addressed the containment of fire, the Convention then prescribes requirements for its detection and extinction. The system to be installed on passenger ships combines these two aspects ie. an automatic sprinkler, fire detection and fire alarm system throughout all service spaces, control stations and accommodation spaces, including corridors and stairways. In addition, a fixed fire detection and fire alarm system is to be installed to provide smoke detection in these same spaces, except for private bathrooms and galleys. The only exemptions from these requirements are spaces having little or no fire risk such as voids, public toilets and similar spaces where neither detection nor extinction need be arranged.

Automatic sprinkler systems have been in existence for many years and have been effective in extinguishing fires. However, the amount of water damage in and near the area of the fire has been significant and a recent development of such systems is the 'water fog' or 'water mist' system which uses much less water to achieve extinction of the same fire. The new technology is mostly in the design of the water spraying nozzle which utilises high pressure to create a water particle size small enough to create a 'fog' in its vicinity and extinguish the fire. Successful extinguishing of simulated engine room fires has also been achieved by water fog systems and approval for their use has been given by a number of Administrations and classification societies for both machinery spaces and accommodation spaces.

However, at the present time, the USCG retains some reservations about their effectiveness and has not yet given approval for their use on US Flag vessels. Those who have given approval for their use have taken cognisance of the technology employed by the nozzle and are ensuring very careful quality control during manufacture together with an insistence that servicing and maintenance is only carried out by the manufacturer. It is to be hoped that, in time, the USCG will recognise the design, manufacture and maintenance controls being exercised and also accept these systems, particularly since they may also offer an alternative to the halon extinguishing systems which are no longer acceptable.

The technology of fire detection systems has also made significant advances in recent years. It is now common to install fire detection systems capable of remotely and individually identifying each detector and the limitations formerly placed on the locations and sizes of sections of detectors which cannot do this have been amended as a consequence. Systems with a zone address identification capability are now to be arranged so that:

- a loop cannot be damaged at more than one point by a fire;
- means are provided to ensure that any fault (eg. power break, short circuit, earth) occurring in the loop will not render the whole loop ineffective;
- all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, informatic);
- the first initiated fire alarm will not prevent any other detector from initiating further fire alarms.

The sophistication of such systems may appear excessive to those familiar with cargo ship construction but the size of modern cruise ships with cabins for about 2000 passengers plus crew cabins, public spaces, service spaces, corridors and stairways all needing detectors, it is imperative that individually identifiable detectors are used. Such systems will inevitably be linked to a computer, or more likely several computers. The control stations of large cruise ships have on-line computer monitoring of many aspects and are likely to include:

- tank contents, stores, provisions and weight distribution for use in the loading instrument (which may include a stability computation capability).
- stability (if not included in the loading instrument) which often includes a damage stability computation capability.
- fire detection system status
- fire extinguishing systems status
- main and essential machinery status
- emergency machinery and systems status

The list is not exhaustive and many other functions are likely to be monitored by computers.

The final safety aspect is evacuation and lifeboats. Apart from the changes from open rowing boats to fully enclosed powered boats and from wood construction through aluminium to GRP, there has been little change in lifeboats other than their size and occasional use as tenders in areas where a vessel has to anchor offshore. Reference has been made earlier to the ever increasing height of the superstructures on modern ships and the consequent need to limit the height above the water from which the lifeboats can be launched. This will add to the intended level of safety for the internal arrangements of corridors and stairways leading to the muster stations and embarkation. However, the expected time taken for the passengers to leave their cabins or other space where they are located at the time of an alarm and progress to the muster stations, embarkation and launch of the lifeboats is likely to take up to one hour even under the direction and control of a well trained and competent crew. The Convention requirements generally address the provision of a minimum of one hour fire protection and full floatability after a two-compartment damage, therefore the time between alarm and clearing the lifeboats should be within a period safe to do so. But, considering the technological and innovative advances in other areas, it is thought that the philosophy of lifeboat evacuation from a ship is ripe for a change.

This has also been recognised at IMO and amendments to Chapter III for entry into force in 1998 include the option of using a 'marine evacuation system', which employs inflatable chutes similar to those used on aircraft. Figure I.5.



Figure I.5
Marine evacuation system showing deployment slide and floating platfom

The aim of such systems is to provide a means of rapidly and safely transferring a large number of persons from a ship with a high freeboard to already launched survival craft, primarily liferafts, since the lifeboats will be boarded and launched at the evacuation deck to a floating platform from which the liferafts can be boarded. The new regulation is in seven main sections, the salient points of each section being as follows:
The construction shall be such that it provides safe descent for persons of all ages, sizes and physical capabilities, wearing lifejackets, from the embarkation station to a floating platform or liferaft.

The strength of the slide or chute is to be to the satisfaction of the administration. The inflatable slides are made from coated fabrics very similar to those used for inflatable liferafts. The vertical chutes are produced from high strength woven aramids such as Kevlar or similar materials, these are translucent or in one case open mesh to admit light.

An inflated slide or passage, as they are referred to in the regulation, must be capable of supporting a load of 150kg at the mid point without undue deflection or distortion. Vertical passages must support a load of 2.2 times the maximum designed load. Both types of passage must be subjected to a test using twice the number of persons it is certified for without mishap.

The bottom platform must obviously be of adequate size for the number of persons for which the system is certified and similarly of adequate strength. It must be self draining, and the buoyancy chambers sub-divided so that the loss of gas in one chamber does not restrict the use of the platform. Bowsing lines or similar, which must deploy with the system, are to be provided to hold it in place.

The system should be capable of deployment by one person. It must be capable of transferring the number of persons for which it is certified to a survival craft in not more than 30 minutes.

It must be capable of coping with trims up to 10° and lists of 20° either way and in the case of an inclined slide should deploy at an angle to the horizontal of between 30° and a maximum of 55°, in the lightest seagoing condition and the final damage condition in the case of a passenger ship respectively.

The capacity is evaluated by means of harbour trial evacuations using a suitable range of "passengers" and in addition a trial deployment should indicate the system is capable of satisfactory operation in a wind of force 6, allied to 3m wave heights. These trials include the launching and inflation of the associated liferafts. Safety considerations means that this sea trial is to be carried out with about 20 properly trained and equipped personnel with adequate standby craft etc.

The liferafts must be stowed adjacent to the passage but sufficiently clear as to avoid them dropping onto the bottom platform.

The stowage container should be properly designed and adequate for shipboard use, but may depend upon whether the system is stowed on an open deck or in an enclosed muster/embarkation station.

Both the container and passage should be marked in accordance with the SOLAS regulation similar to other LSA with approval authority, capacity etc.

Communication between the embarkation station, platform and survival craft is to be ensured. As this will normally be by portable VHF radios, they will be additional to those required by Regulation 6.

Finally, the usual service and training manuals are required and, importantly, adequate shoreside or shipboard training facilities are to be available, including provision for actual deployment of similar devices.

2.7 United States Coast Guard Requirements

Since the majority of cruise ships will either regularly trade from a U.S. port or operate in U.S. waters at some time, then it is necessary to take cognisance of U.S.C.G. legislation which is applicable to ships of all flags who embark passengers in a U.S. port. Such ships are subjected to an Initial Control Verification examination by the U.S.C.G.

Formerly this examination was carried out in its entirety the first time that a ship arrived in a U.S. port. The scope of inspection is extensive and includes matters such as demonstration of the proper functioning of all fire detection and extinction equipment, watertight doors, lifesaving appliances, etc. Crew competence is also checked by holding fire and abandon ship drills. However, one of the more significant problems at the initial control verification examination was in checking the structural fire protection arrangements. This involved the removal of bulkhead and ceiling panels in many locations to enable examination of the insulation materials and their extent of application, method of closing penetrations of fire and watertight bulkheads and the operation of fire dampers in the ventilation system. The time involved in such examinations could be up to one week and the re-instatement of finished surfaces was seldom to the same quality as at the time of build.

In response to adverse comments from Owners and the USCG's own perception that they would be able to perform a better control verification examination if they were to attend the shipyard at critical times during the construction process, such revised arrangements were initiated. At about the same time Lloyd's Register recognised that the informal good relationship with the USCG that had been built up over many years ought to be defined. The result was signing of the Outline of Co-Operation (OOC) to facilitate passenger ship control verification, the principal elements of which are:

General
LR will, during the design, approval and construction of any foreign flag passenger vessel which is classed, or is intended to be classed by LR, ensure that the applicable Coast Guard

standards are applied and complied with. LR will act as the single point of contact to the United States Coast Guard during the examination process.

LR will provide the USCG with its interpretations of international regulations, if any are made, for review and comment along with the Control Verification Check List. The USCG will provide LR with any additional guidance and information, as necessary.

Design and Plan Approval Stages

During the review and general approval of the basic design, LR will advise the owners, designers and builders, of the appropriate Coast Guard standards and will confer with the USCG on all matters of interpretation, including a visit to USCG Headquarters, if necessary, to discuss novel concepts or unusual features of the design.

During the plan approval stage, LR will ensure that the relevant USCG rules, regulations, standards and interpretations are complied with.

During the approval process, should an interpretation or clarification of a Coast Guard standard become necessary in order to carry out the approval process, LR will develop and propose the interpretation for review and acceptance by the United States Coast Guard.

When LR approved plans are submitted to the USCG, LR will provide full documentation of the rules, regulations and interpretation applied during the approval process.

Construction Stage

LR will provide exclusive surveyors who will inspect the ship during construction to ascertain compliance with the approved plans and any changes or revisions required by the USCG.

LR will provide a Control Verification Check List which will also include reference to the approved plans and standards. The completed check list will be included in the ship's records.

LR will recommend appropriate dates for USCG visits to the building yard during construction and assist in planning such visits to ensure that all necessary documentation is available and accessibility to the required areas of the ship is provided in order to facilitate an efficient and satisfactory completion of each examination.

Prior to the first visit to the vessel by the USCG, LR will provide the USCG with a letter from the ship owner stating the vessel's intended area of operation within the United States and the first United States port of call. In addition, at the time of any USCG visits to the building yard during construction, LR will provide necessary assistance to ensure documentation is available and accessibility to the areas of the ship required, is provided. In so doing, LR will recommend the most convenient and suitable dates for USCG examination and assist in planning the visits to facilitate a speedy and satisfactory completion of the examination.

Operation of the OOC is voluntary but when an Owner and Builder agree to its operation, the final USCG control verification examination of a vessel on arrival in U.S. waters is reduced to about half a day and chiefly involves a demonstration of crew competence in fire and abandon ship drills and verification of the ship's documents.

2.8 Final Comments

Approval of the necessary plans and forwarding these to the surveyors at the building port is not the end of involvement by the HQ passenger ship specialists. Visits will be made to the shipyard to assist the local surveyors with general progress and to discuss revised arrangements which become necessary due to Owners or Builders changing requirements.

The specialist surveyors will also be present for USCG visits and at the time of issue of the Passenger Ship Safety Certificate when the ship delivers.

Part II

New Construction, the Initial Passenger Ship Safety Survey

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1 Introduction

In recent years the rapid growth in the passenger cruise market has led to a flood of orders and construction by yards with no previous experience in this type of vessel.

Associated with the this rapid growth there has also been a rapid development of specialised solutions to service these complex ships in areas such as panel systems, piping systems and safety technology. There have also been changes in the way the ships are built as owners have insisted on shorter and shorter delivery times, and the yards have had to squeeze lead times for the design and speed up outfit to accommodate them. The way in which the steelwork is fabricated has also changed with a high degree of automation now being involved, including the introduction of sophisticated welding robots on the panel lines. But the most fundamental change has been in the way in which the ships are fitted-out with an enormous amount of outfit at the prefabrication stage. At launch, vessels are now up to 50% complete. New piping systems and panel systems are also helping to speed things up, being simple and fast to install by unskilled workers.

This has complicated the Surveyors life and increased the need to ensure that good records are kept at all times. Insulation in particular and, to a lesser degree, ventilation ducting are able to cover a multitude of welding and structural defect sins if not seen at the right stage of construction. This speeding up of the shipbuilding process and particularly the reduced lead times has led to the need for an improved response time from plan approval offices. The arrangement of having a single Co-ordinating Surveyor in Headquarters who is responsible for overseeing the project and approving the plans, has proved particularly successful under these circumstances since it provides the field Surveyor with a focal point for the clarification of uncertainties, when required, and enables full involvement in the plan approval procedure.

Due to the complexity of these vessels and the way in which the finished panelling hides other outfit and equipment, the state in which the ship leaves the shipyard is that in which it will continue throughout its working life. It is important to keep this in mind when carrying out the Initial Survey.

2 Steel Construction

2.1 Structure

The steel arrangement of the majority of passenger cruise ships tends to be similar due to statutory and physical constraints. The modern cruise vessel has little in common with the traditional type of passenger liner which was built up to the 1960's.

The structural arrangement of a modern passenger cruise vessel is one of beams supported by pillars, longitudinal framing and, of course, many decks. A recess is provided in the side of the vessel to house the lifeboats and use is made of this to make a passenger promenade. In larger vessels all longitudinal stiffening is of high tensile steel.

A finite element analysis is carried out, to determine the highly stressed areas thus allowing refinement of the steelwork and, for the field surveyor, concentration of NDT in the most vulnerable areas. Attention to detail in these highly stressed areas is of critical importance. The longitudinal bulkhead and decks around the embarkation deck are highly stressed as are areas around shell openings. These will probably be of high tensile and notch toughened steels. The finish of openings and corner radii must be carefully controlled since they are easily damaged by careless outfit. Openings in the deck, of which there are many, should be adequately compensated.

The size and thickness of decks and longitudinals are reduced to the minimum (as small as 80 mm) and the number and size of lighting holes is maximised in order to reduce as far as possible the passenger vessels continual problem of excess weight. These vessels are normally constrained by breadth and always by draught. Breadth to allow transit of the Panama Canal and the speed power relationship with draught to enter ports of choice.

Plan approval is done in two stages; an assessment of the structure based on the rules and, subsequently, a review of the drawings based on the results of the finite element analysis. There are therefore necessarily two sets of amendments to consider. Unfortunately, the second part of the process can be after the bulk of the steel has been ordered with a consequent requirement for equivalent arrangements to be accepted. The structure appears very 'delicate' and 'complex' when compared to a cargo ship. There are many areas where misalignments can occur and these should be rigorously checked during the block construction and block join up stages.

Passenger vessels normally have large numbers of pillars and care must be taken to ensure that continuity between them is maintained at each deck. Sufficient stiffening should be fitted under them, on the deck beams, and cut outs in beams and girders should be filled. Where a change of deck beam section occurs, the cut outs should be closed to prevent buckling of the web. Figure II.1.



Figure II.1
Internal structural arrangement

However, the major structural problems take place after the steelwork is complete and is generally caused by unskilled workers using cutting equipment to open passages for cabling and ventilation ducting in beams and girders, and openings in structural bulkheads for doors and windows. The situation is greatly improved, however, if the design plans are approved with the maximum possible number of lightening holes of a standard size and the shipyard orders cable trays and vent ducting specifically to fit those holes. This reduces the amount of cutting required and it is known in advance that any additional openings will require compensation. All openings should have suitably radiused corners regardless of their position. On occasion some openings may be unacceptable, even with increased stiffening. The finite element analysis can help to identify such critical areas. Figure II.2.

In view of the fact that all longitudinals and girders are of high tensile steel the attachment of minor items such as pipe supports and cable trays should be carefully controlled so as to avoid notches. It is important to avoid welding directly onto the bulb or openings in beams and girders. Much of the steel outfit work may be subcontracted and consequently some workers involved in the outfit may have no previous experience of working with highly stressed steel structures. The fitting of stairways and vent ducting in particular are known to cause problems.

2.2 Welding

Where shipyards have been involved in the construction of normal merchant vessels such as tankers and bulk carriers, they may well experience some difficulty in changing over to the lighter scantlings of passenger vessels. Typically, decks for these ships are only 5 mm thick. The problems which can arise are largely overcome by investment in semi-automatic welding machines and retraining of personnel.

Welding techniques have been developed to minimise heat input, with extremely light one sided continuous welding (down to 4.5mm leg length) and double continuous welded longitudinals welded to 3mm leg length now being accepted. Vertical fillet welds are generally welded downward on the smaller sizes. This has however given some cause for concern since it is highly dependent on the skill of the operator and cracks can sometimes be found at the start point where the weld metal cools rapidly. Whilst large amounts of high tensile steel are used in these vessels (all the longitudinals are high tensile steel, as are the girders) it is interesting to note that this is not always welded double continuous, but continuous on one side only is frequently employed. This process has completely replaced intermittent welding in some shipyards, as it lends itself well to automatic processes. Where high tensile steel is used for decks however this is often, but by no means always, welded double continuous. The owner will normally require that wet spaces, e.g. pantries, galleys, toilets etc. and, of course, external areas, to be welded double continuous, or at least on the wet side.

The Builder makes a clear distinction between structural steel and steelwork fitted for structural fire protection purposes, the steelwork drawings being approved without any of the fire bulkheads shown. This allows Builders the flexibility to make changes to the layout of spaces on the vessel as necessary during construction. All steel fire bulkheads are made of corrugated material and welded from one side only. However when attached to high tensile steel plating (where longitudinals are welded double continuous) it should be welded double continuous as should all fittings.

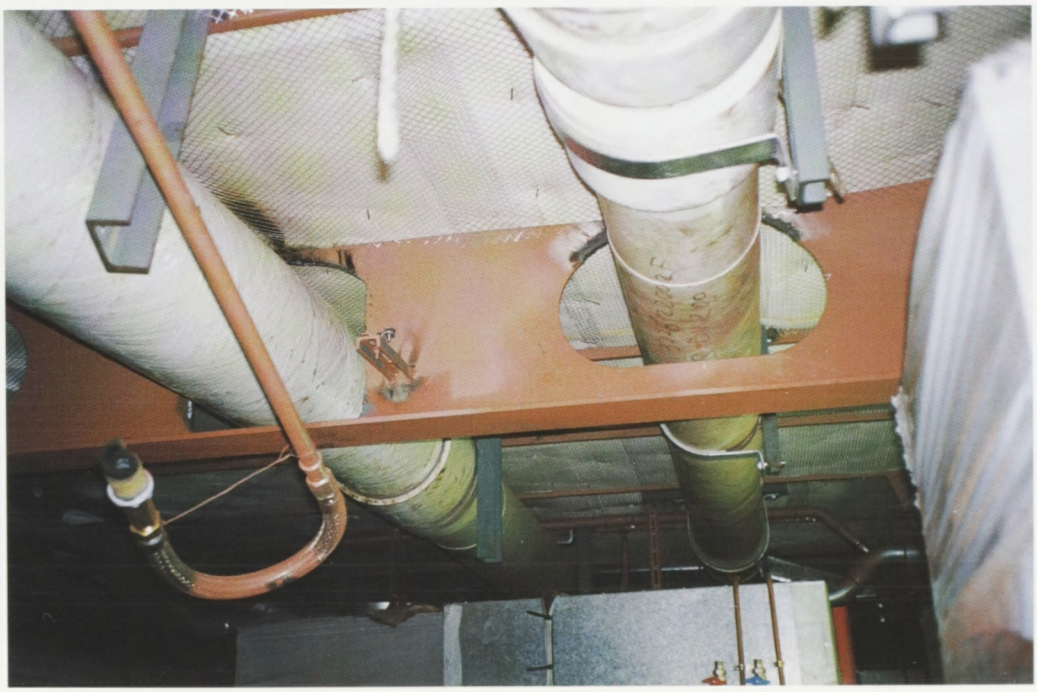


Figure II.2
Unauthorised cutting in beam

2.3 Fairing

Because of the light scantlings, shell and deck plating suffer from deformation during construction in spite of the measures described above. This is unacceptable to both the Owner and Builder, since a flat shell is required for good appearance and level decks are required to reduce the amount of fairing compound used to obtain a level finish. Unless preventive measures are taken, the large amount of fairing that is required can cause problems with buckling of deck beams under the decks being faired and particularly anti-racking and other transverse bulkheads. The failure mode of deck beams has been found to be by distortion of the face flat rather than tripping since, typically, these vessels have tripping brackets connected to the face flat every second longitudinal which produces a very stable element.

3 Watertight Integrity

3.1 Watertight Doors

Modern passenger ships have large numbers of watertight doors, 42 in the case of a recent large new building. Whilst this is probably more than was envisaged when the rule "that their number should be no more than the minimum compatible with the design and proper working of the ship" was drawn up, they are a necessary consequence of the subdivision required for damage stability compliance. Watertight doors are normally required in the accommodation spaces to provide the secondary means of escape and in the engine spaces too allow the ship to function efficiently. Figure II.3.

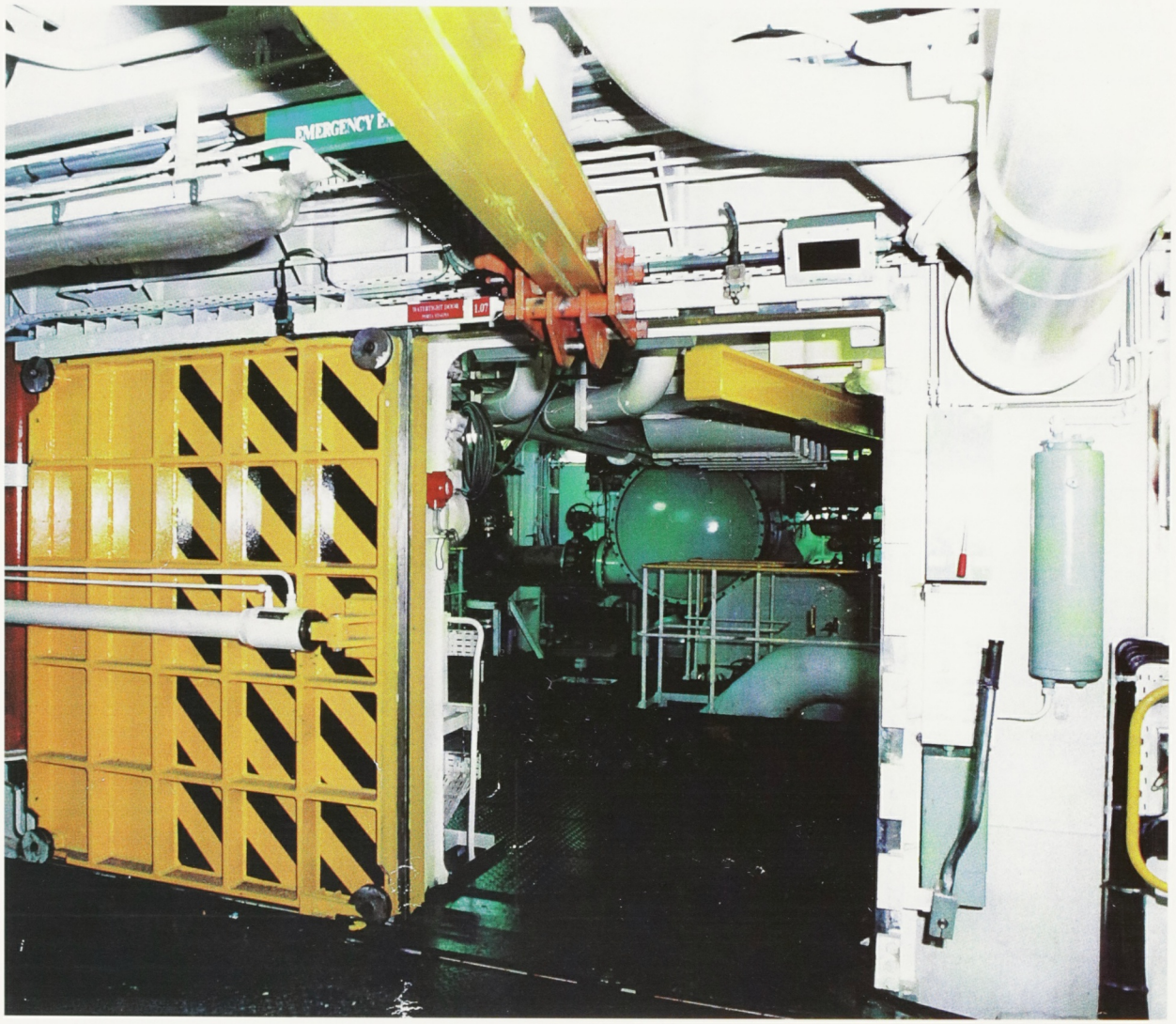


Figure II.3
Watertight door in machinery area

Under certain circumstances doors are required to remain permanently closed, that is to say they can be opened only when the operating handle is held in the open position. Release of the handle will cause the door to close. This may be required because the door is outside of the theoretical damage penetration area of B/5, or because it is the second door in a machinery space watertight bulkhead. SOLAS allows for only one door in a machinery space bulkhead. Doors greater than the maximum allowable width of 1.2m have, on occasion, been accepted with a mechanical device to prevent them opening to more than this width except in exceptional circumstances, such as to pass spare parts into a machinery space. When either of these cases occur, instructions must be clearly marked on the door and a note made in section 11.0 of the Record of Passenger Ship Safety Equipment.

When watertight doors also act as fire doors it is not necessary to insulate them, whatever the fire rating of the bulkhead in which they are fitted, since this is specifically exempted by SOLAS.

Watertight doors may be powered by:

- a centralised hydraulic system with two independent motors and pumps, each set being capable of closing the doors on their own;
- an independent hydraulic system for each door;
- an independent electrical system and motor for each door.

SOLAS envisages that watertight doors are normally kept closed at sea. Unfortunately, in practice, this makes the vessel difficult to operate and certain doors are allowed to be normally left open. Doors must be provided with a mechanical (manual) means of opening and closing on each side and also a means of closing from above the bulkhead deck. Power operation should be provided on both sides of the door and a means of closing from the bridge. Audible and visible alarms are provided to alert passengers and crew that the door is about to close.

There are two types of door in general use, the traditional type which are very heavy and rely on a mechanical seal between metal surfaces and the gasketed type which use the head of flood water to press the door onto a seal.

Doors will normally arrive from the supplier already pressure tested. Care is to be taken to ensure that they are fitted on the correct deck since the test pressure may have been dictated by their depth below the damage waterplane. Since the frames of these doors are very heavy it would be difficult for them to be distorted in transit, however, it is a good idea to check the facings for damage. Some doors are designed to sit in a trough. This interrupts the longitudinal framing which should of course be compensated and extra stiffening should also be fitted behind the rams and rails as necessary.

Cables and piping supplying control information or hydraulic oil should be routed so as to minimise the likelihood of them being involved in any damage which a ship may sustain. They should, as far as practicable, be near the centre line and certainly outside the B/5 damage zone. Where doors are fitted in or near this zone the piping and wiring should follow, as far as is practicable, the line of the bulkhead in which the door is fitted. Indication to show whether the door is open or closed should be provided at the bridge and at the hand operation station above the bulkhead deck. In accommodation areas care must be taken to ensure that the continuity of B class boundaries are maintained around watertight doors. Figure II.4.

Whilst pressure testing on board is acceptable, if somewhat impractical, the doors should have already been tested in the factory. Subsequent on board testing of doors with a mechanical seal is best carried out with soap and air and feeler gauges to ensure the fit is good.

The doors should operate from the emergency source of power and automatically from a transitional battery source of power. If they are hydraulically driven this will require the doors to have some form of stored energy with the control system powered from the transitional source of power.

The satisfactory operation of watertight doors is to be tested during the sea trials. Testing should include:

- Check of identification marks against certificates. Note that the doors may have been tested with different heads, so it is important to have the correct door on the correct deck.
- Check of welding and stiffening.
- Pressure test piping and check cleanliness of system, particularly oil tanks and piping. The hydraulic oil should be circulated through filters to ensure that no foreign matter is left in the system.
- Check manual operation at the door. It should be possible to close the door manually within 90 seconds using the hand pump. Check that both hand pumps work, and that their operation is not impeded by panelling or other outfit.
- Check manual operation from above the bulkhead deck, including operation of the alarm. Note that it is not necessary for the alarm to sound before the door starts to move in this mode of operation.
- Check local power operation when remote closed/open. The door should close in no less than 20 seconds and no more than 40 seconds. The handle should be positioned at least 1.6 metres above the deck. It should operate in the direction in which the door opens. It should be possible to open the door and pass through without having to release the control handle. Check the gas pressure in the accumulator bottle if applicable.
- Check operation of audible/visual alarm. The alarm should start to operate 5-10 seconds before the door starts to close, when operated from the bridge. All the electrical components should have protection against damage by water. The alarms and indicators should have an IPX6 rating, the movement warning signals IPX8 and electric motors, where applicable, IPX7.
- Check closing from the bridge takes place in less than 60 seconds. Note that it should not be possible to open the W.T. doors from the bridge.
- Check bridge panel mimics/alarms. Some of these may have to be simulated. They include low oil pressure, high temperature and low oil level.
- Check accumulator closing (if applicable). The stored energy should be sufficient for three operations; closed-open-closed. Ensure that the door closes completely on the third operation as the potential energy is at its lowest. Start



Figure II.4
Watertight door control station above the bulkhead deck

the test with the pressure dropped to the point where the pump starts.

- Check controls are properly positioned and instructions posted. When the door is to remain closed at all times, ensure that this is clearly stated in the instructions. Ensure that the door-in-motion alarm continues to sound even when the door is in the completely open position.
- Check power supplies to the door, including operation from the transitional source.

3.2 Shell Doors and other Shell Openings

A number of shell doors are normally provided on passenger ships to embark stores, water, bunkers, crew and passengers and, more recently, to disembark passengers into tenders to take them ashore when the vessel is at anchor. This latter function can also involve provision of have embarkation platforms against which the tenders can be moored and, consequently, are quite large structures.

Where the door has a lot of shape, it is sometimes fabricated on board with the stiffening welded to the existing shell before being cut out to ensure that a fair hull form is maintained. Shell doors are often arranged to open inwards and, in these cases, they should have a strong back fitted. In recent designs this has been integrated into the door. Pins fitted to secure the strong backs should be permanently connected by means of a chain or similar. Where hydraulic cleating is used the closing arrangements should be such that the door cannot open due to a hydraulic failure. This requires the fitting of a pin in one of the locking arms. Means should also be provided to secure doors in the open position. Figure II.5.

Doors of greater than $12m^2$ clear opening are the subject of particular requirements and the Rules for Ships should be consulted. However, such openings are quite unusual.

After fitting, shell doors should be subjected to a chalk test and subsequently a hose test, the former to demonstrate the pressure on the gasket material is even, the latter to ensure that it is watertight. Metal to metal contact should be provided to ensure that the rubber packing material cannot be over compressed.

Whilst the fitting of indicator lights at the bridge is not obligatory for doors under $12m^2$, these are normally provided and should be tested. Ensure that the door is completely closed and locked before the closed indicators illuminate.

3.3 Watertight Subdivision

The adoption of the 1988 Amendments to SOLAS, MSC 12(56) concerning damage stability criteria necessitated a fairly radical change in the layout of the working spaces on passenger vessels on and above the freeboard deck. Since intermediate stages of flooding are now considered, it may be necessary to continue the watertight bulkheads above the freeboard deck to restrict the theoretical flooded damage waterplane. At the shell in the ends of the ship this may be as much as two decks above the freeboard deck, where the hull form is fine and consequently the trim of the vessel will that much greater in the damage condition. It is important to ensure that these bulkheads do not have any non-watertight penetrations or have spaces on each side connected by scuppers. The steelwork must also be complete. It is easy to find welding scallops left open in these areas. Theoretically, in case of damage, these areas are only flooded for a limited period until the vessel returns to the final equilibrium position or during rolling in a seaway.

Most large vessels are built with down flooding ducts. These are watertight trunks which are designed to transfer accumulated water from upper decks into the bilge. They may span two or three decks and care must be taken to ensure that structural fire protection requirements are maintained between decks. Great care should also be taken when assessing the pipe-work for Load Line aspects to ensure that scuppers cannot cause flooding of adjacent compartments. This can happen particularly when decks

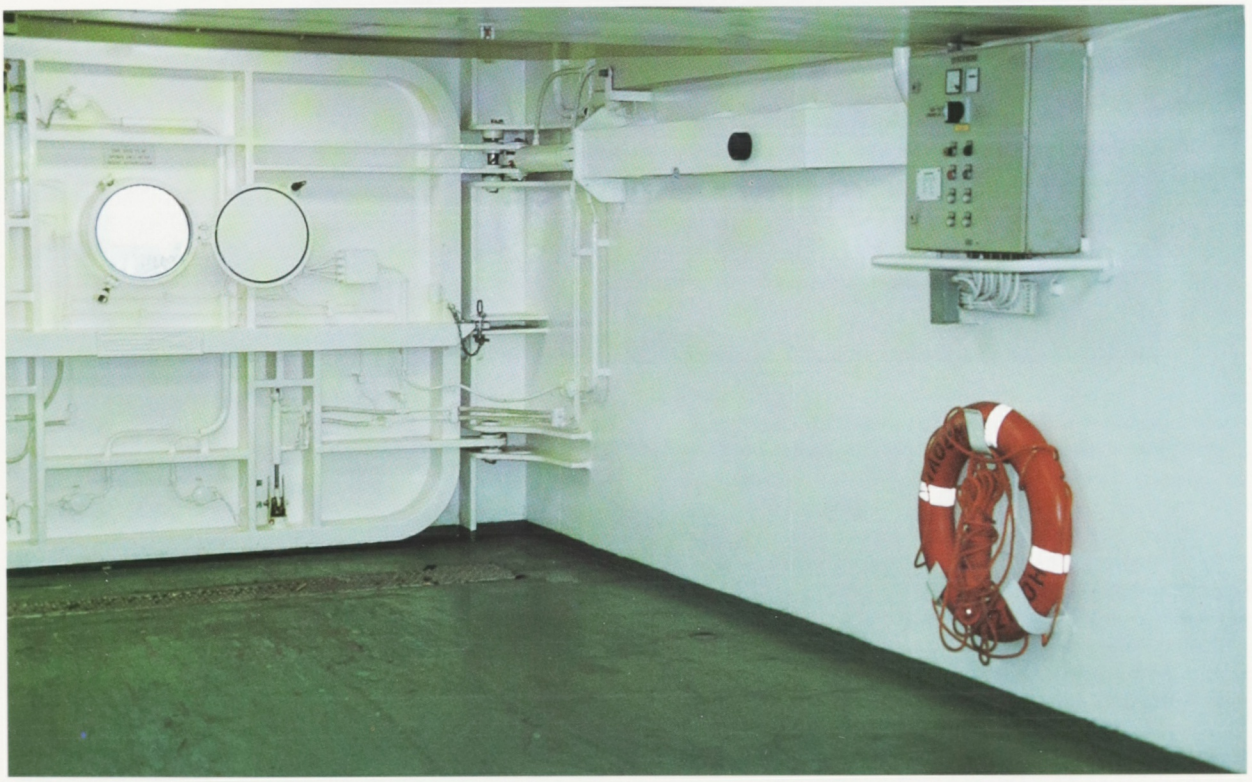


Figure II.5
Weathertight shell door

form steps in watertight bulkheads, with the scupper draining on the wrong side of the bulkhead. This may sound obvious, but on a plan it is difficult to identify them. It is also important to note that where piping is outside the B/5 line, it should be considered open in the damaged condition and treated accordingly. Grey and black water tanks may not be watertight but, if they are, may have vents or overflows that render them open for flooding. When plastic piping penetrates watertight bulkheads it is normally necessary to fit remotely controlled valves with their controls located above the bulkhead deck.

Reference has been made to the possible need to restrict the extent of flooding on or above the bulkhead deck in some damage stability scenarios. Therefore, consideration must be given to the construction of the bulkheads preventing such flooding together with any doors in them and their sealing arrangements. These bulkheads and doors need not be watertight in the accepted sense with respect to pressure heads of water and to call them weathertight is inappropriate. The expression water-resistant conveys the principle intended, although the term splash-tight seems to be in common use in shipyards. Such bulkheads would not necessarily have to meet the scantling rules for watertight or non-watertight bulkheads, unless they were also carrying other loads such as racking or pillar loads. An "A"-class fire division, being of steel, properly stiffened, and welded all round would meet the requirements. However, an "A"-class fire door would not be adequate and a door of more substantial construction and having some sealing arrangements is required. Detailed guidance notes on this aspect were finalised by the International Maritime Organisation Sub-committee on Stability and Loadlines at their 34th session (SLF34). The doors are to be closed from a central station and also to be capable of being opened and closed locally. The scantlings and sealing arrangements are to be sufficient to withstand the greatest head of water that could occur in practice and the doors are to be able to operate as above when subjected to that head of water.

The principle of allowing water on the bulkhead deck and then restricting its spread gives rise to a conflict with another area of the regulations. In Chapter II-2 Regulation 28 deals with "means of escape" and distinguishes between escapes from spaces above the bulkhead deck and those from below. At least one of the escapes from below the bulkhead deck is to be independent of any watertight doors in the bulkheads. This is not the case for escapes from above the bulkhead deck because watertight doors have not previously been used there. Escape routes in such areas therefore require careful consideration to ensure that a viable escape always exists.

This change in legislation has had an impact on the design of ships but the construction methods and public space layouts probably have had more effect on the need for legislation change. Examination of the profiles of ships since the "TITANIC" show a steady increase in the proportion of ship above the bulkhead deck compared with that below it which is largely unchanged. This has affected the windage of ships, which has had to be corrected by side thrusters to ensure adequate control. It has caused problems with lifeboat location and launching resulting in regulations restricting the maximum allowable launch height. Deck sheer in older designs was a method by which the transverse bulkhead subdivision spacing could be maintained equally throughout the ship but the modern construction method using flat decks, means that subdivision must be reduced at the ends to ensure that margin line immersion does not occur in flooding scenarios.

SOLAS requires that watertight bulkheads are subject to a hose test. It is believed that this requirement dates back to the days when ships were rivetted. The relevance of this test in today's fully welded ships is not obvious and, since shipyards tend to do an enormous amount of pre-outfit, it is difficult to programme. It is hard to imagine what could be gained over a close up survey and dye penetration check of attachments passing through a bulkhead, especially since the hose test would be carried out before cable or pipe penetrations were fitted.

When checking the watertight bulkheads, it is important to ensure that any steps caused by escape trunks or ventilation ducting are constructed of structural steel and not corrugated material used for fire bulkheads which may not be able to withstand the flooded head of water.

4 Lifesaving Appliances

4.1 Davits for Liferafts and Lifeboats

Liferaft davits fall into two groups; underdeck and pedestal type. Until recently these davits could handle rafts for up to a maximum of 25 persons. However, larger ships have necessitated larger rafts and davits are now available for rafts carrying a maximum of 35 persons. Ships lifeboats are limited to a maximum of 150 persons but even these are very large boats and, especially when of the lifeboat/tender type, result in a very substantial davit system.

It is of note that lifeboats for cargo ships must be totally enclosed but for passenger ships partially enclosed lifeboats remain acceptable. Places in lifeboats provided for passenger vessels are also much more limited than those for cargo vessels with most crew members being accommodated in liferafts, albeit davit launched. Spare capacity accommodates just 25% of the persons on board.

The traditional radio station for passenger vessel lifeboats has also disappeared, since they are no longer in production, and two normal lifeboat radios would suffice. It is expected however that all new ships will adopt the GMDSS solution since it is more cost effective and will be a statutory requirement from 1999.

In order to comply with the IMO recommendations that lifeboats should be positioned no more than 15m above the waterline, for larger vessels they have to be housed in a recess in the vessels side. This recommendation has been almost universally adopted on new buildings and has led to use of a new type of lifeboat davit which is power rather than gravity operated. This requires a smaller recess than would be necessary for a gravity type system. Two different types of davit have been fitted. The earlier ships had a type of flattened gravity davit, the arms being pushed out by hydraulic rams, whilst later ships use an underdeck stored power type (UDSP) with a complex system of wires and sheaves and are connected to hydraulic rams. The design of these underdeck davits is being constantly refined and modified, however, the means of powering them remains the same. In each case hydraulic power is provided by two independent pumps driven by the emergency source of power with back-up provided by stored energy in the form of nitrogen gas. Each davit has an independent system powered by stored nitrogen. There is also a hand pump provided, but this is considered of limited value due to the slowness of operation. Figure II.6.

The latest Schatt design of davit consists of simple travelling beams powered by hydraulic pistons. Pressure sensors ensure an even speed of movement , out of synchronisation causing an increase in pressure. These systems require alarms for low oil and gas pressure, oil temperature, oil level etc. which may be duplicated in the wheelhouse and on the UMS alarm system. It should be remembered that the alarms should be powered from the transitional source of power. For this reason operation of the alarms through only the UMS system is not acceptable. This also applies to other systems such as CO2 and sprinkler.



Figure II.6
Telescopic UDSP davits in the deployed position

4.1.1 Testing

Davit systems require a proof (static) load test of 2.2 times the safe working load (SWL). This may have been carried out in the workshop or may need to be carried out onboard. The proof load on the hydraulic system due to the resolved components of trim and list, 10° and 20° respectively, can be simulated either by fixing the arms in the almost fully extended position and increasing the pressure to the required amount, or by using a weight and a series of pulleys to simulate the force in the required direction. The steelwork around the davits should be suitably stiffened and the welding carefully checked. The davit structure tends to be of considerably heavier scantlings than the structure surrounding it which should be examined for distortion after the load tests.

The testing at 1.1 x S.W.L may be carried out using caissons filled with water since there are problems with lifting the test weights out to the seaward side of the vessel. Test weights can be up to 12 tonnes per arm. For the same reason it is logical to do the brake test and speed checks at the same time. Experience has shown that differences in weight of the order of 10% make no difference to the speed results obtained. When speeds are found to be outside those required, it is necessary to change the spring ratings in the brake assembly. The sheaves for UDSP systems are often fitted separately and the correct alignment of these is most important. Misalignment causes increased wear on the cables.

The one part of the system that seems to give a lot of trouble at the installation stage and also with the ships in service, is the remote operation of the brake. It is understood that wireless systems are currently under development but that they have experienced problems with radio interference. If this can be resolved then a major improvement in the working of these davits will result. Lifeboats will probably arrive from the factory fully tested. Overload tests and tests such as the on-load hook release are much better carried out under the controlled conditions available in the factory.

4.1.2 Lifting and Travelling Wires

When the wire ropes arrive in the yard, check them against the certificates, and mark them in some indelible way such as with coloured paint if they are not immediately recognisable from the diameter. Once the wires are in place it will be extremely difficult to identify them.

4.1.3 Tender Davits

There are some interesting points to consider when looking at tender davits. The davits are heavily loaded and subjected to frequent use. By heavily loaded it is meant that whilst the calculations are done with the same safety factor as for an ordinary lifeboat davit, an empty tender is proportionately much heavier than an empty lifeboat. Indeed, a typical tender when empty weighs twice that of the equivalent lifeboat. It is also true to say that whilst a ship might not carry out a lifeboat drill in bad weather, tenders are often operated in quite large waves which can cause the boat to be "dropped" onto the falls. Frequency of operation is also a factor, with tenders being operated every day in some areas of operation. This increased wear is confirmed by the fact that the wires have, on occasion, had to be changed after only two years in service. Figure II.7.

It is known that some crews cut a small length out of the falls every year to alter the point of greatest wear, where the wires run over the sheaves. This obviously results in the wire being shorter than intended and should be borne in mind when fixing lengths. Note also that the wires should not be too long, so as to ensure that they run on to the drum correctly. The wires tend to be delivered with some additional material which should be cut off or the wire may abrade as it runs onto the drum.



Figure II.7
Tender davit in deployed position

5 Fire Protection

The importance of this aspect of passenger ship new construction cannot be over emphasised and, in order to carry out these surveys effectively, it is necessary to be physically fit, well organised and to have a good knowledge of the regulations.

Fire safety can be divided into two broad parts, passive protection (structural fire protection, escapes, restricted use of combustibles, etc.) and active protection (detection and extinction).

The modern passenger vessel is a steel box which is divided into vertical zones. Each of these zones is designed to contain a serious fire. The boundaries of main vertical zones are generally A-60, but may be reduced to A-0 where little or no fire risk exists, as in the case of sanitary and void spaces. Ventilation systems, sprinkler zones and fire detector zones are all maintained within the length of a single main fire zone.

Main vertical zones are themselves divided into areas which are categorised by their contents and use. The boundaries of each space are assigned a level of fire protection dependent on their fire risk and importance in case of an emergency. The appropriate protection of the divisions separating adjacent spaces is given in the tables of Regulation 26 of SOLAS Chap II-2.

The control of the various safety systems such as ventilation dampers, W.T. doors, sprinklers, fire alarms etc., must be grouped in a centralised control position which may be the bridge or an independent emergency centre. It is required that a unified system of indicators is used for the control panels, (i.e. red means open and green closed) so as to avoid confusion.

5.1 Passive Systems

5.1.1 Conduct of Structural Fire Protection Surveys

It is important to carry out a close up inspection of all spaces on board prior to their being panelled, where applicable, or on their completion, to ensure that the correct level of structural fire protection is in place. This is probably the single most time consuming item that a Surveyor has to cover during the construction of the vessel. It should be given the highest priority since many of these spaces will never be seen again during the life of the ship.

Experience has shown that it is important to be well organised for these surveys and to keep detailed and precise records, particularly if more than one person is involved in the surveys.

When carrying out these inspections it is useful to have available the following items:

- A copy of the approved structural fire protection plan, preferably scale 1:100, made into the form of a book on which notes of defects and damages can be made and a record of the spaces seen can be kept.

- A copy of the Regulation 26 tables, showing insulation requirements. A copy of Regulations 16 and 32 for ventilation systems.
- A copy of the insulation type approval showing its means of attachment to bulkheads, decks, etc.

The passive structural fire protection is best checked in the following way:

1. A pre-insulation inspection. Check that no scallops are open or other structural items are left unfinished. Check that the pins to secure the insulation batts are correctly spaced. It is also a good idea to mark on the copy of the structural fire protection any cable passages, since these are often difficult to see once the outfit is advanced, and any other items that could be covered up by insulation.
2. Structural vent duct inspection; check thicknesses (3-5 mm), penetration lengths (900mm) and welding.
3. Insulation inspection; check the category of the space against the approved structural fire protection since the use of the space may have changed. Check that the correct insulation rating is being applied, using the tables in Regulation 26. It is best to use the structural fire protection drawings as a guide, since modifications may have been made. Check that the insulation is applied at the correct thickness and in the correct way, particularly the overlaps of insulation.
4. Pre-panelling inspection; check that the cable passages and other openings are closed, and that the vertical draft stops are fitted in the correct places. Take careful notes of any outstanding items. The importance of this cannot be overstated. Mark on the structural fire protection plan any cable or other penetrations, indicating whether they are open or closed.
5. Pre-ceiling inspection; check that all the penetrations for cabling and piping are closed with approved products, that vertical draft stops are complete and that longitudinal and transverse draught stops are correctly fitted. Check that cable runs are secure and that cables are securely clipped, as required by the rules.
6. After ceiling panels are complete, finally inspect draught stops, sprinkler placement etc. Spot check that the B class insulation in ceilings is complete especially where lights and speakers are fitted since these may have interrupted the required fire integrity. Check that access to valves, dampers etc. is provided.
7. Check also, in the case of stairways and public spaces, that the requirements of low flame spread and fire load are met. Ensure that certification is available for all materials used. Check that the B-class panel system has been correctly applied.

Keeping good records provides a feeling of confidence and of being in command of the situation as well as ensuring that the work is correctly carried out. Probably the most important note of all, is that every item should be seen, this type of work does not lend itself to random spot checking. It is difficult to examine behind panelled spaces during the vessels life and, consequently, any structural problems or deficiencies in the structural fire protection may remain undiscovered even during subsequent Periodical Surveys.

5.1.2 Flammables and Low Flame Spread Materials

SOLAS II-2 Regulation 34 brings together the requirements for low flame spread and combustibility of materials. Primary deck coverings, such as self levelling compounds which are used extensively, should be of an approved type.

Insulation for refrigerant piping was formerly a problem since it should have particular flame propagation properties and it was necessary to cover the insulation with glass tape. But this has been negated by the introduction of approved products, such as Armaflex and similar, which have self extinguishing characteristics, and are also approved for toxicity levels.

The Builder is required to produce calculations for the fire load of various spaces on board such as cabins, public areas etc. The results are generally well within the rule requirements and anything other than a quick verification check at the ship is unnecessary.

However, during surveys it is important to control the materials used in areas which require low flame spread characteristics. In public spaces the wall fabrics may well be flammable and should be supplied with suitable certification. As a general rule, the materials used in spaces which are not visible, i.e. behind linings, should be non-combustible. A limited amount of combustible materials in view, and therefore covered by sprinkler protection, are allowed. Specially treated wood products, designed and certified to satisfy the above, are available for dance floors.

5.1.3 Bulkhead Penetrations

Various approved types of cable transits are available, four common types in use in Italy are described here. Builders generally have problems with cabling since they are unaware until late into the building programme of the exact number of cables that will have to be passed through watertight and fire divisions and therefore the number of cable transits that will have to be provided. This can lead to overloading of cable transits and cable trays.

Modular systems such as Roxtec and CSD are suitable for use above or below the bulkhead deck where watertight integrity is also required of the cable transit. These consist of a welded collar into which rubber blocks are fitted, each block containing one cable. These are then compressed by means of a special bolt. Such systems are expensive in both time and material costs and lack flexibility in that they are designed for a clearly defined maximum number of cables. They can, however, be closed from one side of the bulkhead and can be reopened to allow additional cables to be passed easily. From the Surveyors point of view they are easy to check and difficult to fit incorrectly. Ensure however that the spacer plates are correctly fitted and that the collar is completely welded. Figure II.8.

Geaquello is an AEG product which is extensively used. It is heavy, expensive and time consuming to prepare but, extremely effective. The passage consists of a steel sleeve through which the cables are passed. The ends are then filled with an approved sponge material supplied with the filling compound, which expands when wetted out to form a seal. The sleeve is then filled with the Geaquello compound, which is similar in consistency to cement.



Figure II.8
Modular bulkhead cable penetration at end of fire test

Ensure that there is good separation between the cables (5 mm) and that the sleeve is completely filled. Since Geaquello shrinks on hardening, it is necessary to top up the sleeve after the first pouring has set. Figure II.9.

Ensure that clean water is used, or the Geaquello will not harden, and that it is completely liquid when poured. This type of cable passage requires access from both sides of the bulkhead and, once filled, has to be drilled out in order to pass further cables. The sponge material can be left in once the passage is complete. However, it is prudent to ask for the top strip to be removed to ensure that the passage is completely full.

RTN is a new product with impressive insulation properties. Its development derives from the Space Shuttle programme and it is sprayed over Seawolf missile casings to prevent them exploding in case of fire. It is however difficult to apply to a uniform standard, and depends very much on the skill of the operator and degree of access available. Its extraordinary insulating properties however mean that a layer only 10 mm thick is sufficient to provide an A-60 level of fire protection. The system is applied as follows. Clips are fitted around the opening to provide a key to which the compound can be applied. Cable separation is again important and provided by an inert foam material over which the paste is laid. Whilst extensive testing has been carried out on this product, it should be treated with caution. The only way to ensure that enough of the product has been applied is to ask that test drilling be carried out on occasion. At present this product is not suitable for use below the bulkhead deck. Although tests have been carried out to show that it is watertight, experience has shown that whilst it may appear closed, gaps can exist.



Figure II.9
Proprietary compound bulkhead cable penetration

Boero is a two part product used for small diameter cable passages. The cables are passed through a steel pipe of 100 mm in length, which is then filled with this two part mastic. The material hardens in about 12 hours, and herein lies its greatest defect, retention of the liquid material in the steel tube. It has been found on many occasions that contractors have stuffed glass wool into the end of the tube to which the Boero readily sticks and appears complete. Again, the only way to check is by test drilling.

There are many other approved alternatives and builders will use the products which are readily available at the right price in their area. Whatever is used, care must be taken to ensure that it is fitted or applied in accordance with the fire approval certificate details and manufacturer's instructions.

To increase flexibility, fewer and fewer pipes of the traditional steel flanged type are being used. Except in the case of some special pipes such as the fire main, sea water and chilled water services, almost all piping systems outside of the engine room are now of stainless steel press fitting type for compressed air, domestic water and sprinkler pipes, Loro-X galvanised thin wall pipes for scupper pipes, and black water pipes, or plastic (GRP) for ballast lines and air pipes. In the engine room, titanium press fitting will soon take the place of CuNiFer, and press fitting stainless steel is used for much of the non-essential services.

All the above require specialised bulkhead transits. Stainless steel piping is usually fitted with C.S.D. type plugs, or specially fabricated close fitting mild steel sleeves, which are applicable in both fire and watertight bulkheads. The former consist of a serrated rubber two piece fitting, which is hammered into a metal sleeve. As long as the correct dimensions are chosen , they are difficult to abuse. They are also very efficient, being able to withstand a head of 3 bar even after a standard fire test.

Loro-X systems have cast inserts, with their press fitting type couplings built in, which are welded into bulkheads. These are generally used above the bulkhead deck for scupper pipes and similar, but can also withstand quite high pressures when required.

The most interesting system however is the Geberet system of bulkhead penetration for plastic piping. At fire divisions, a hole is made of slightly larger diameter than the pipe over which is placed a Geberet trap (Figure II.10). This is a stainless steel sleeve made in two parts each of which contains a blade held on a compressed spring, retained by plastic pins. Also contained in these are packs of intumescent material. In case of a fire the pins melt releasing the blade which severs the pipe. The heat causes the intumescent material to expand thus closing the bulkhead. This seal however is not waterproof and consequently these traps cannot be used in watertight bulkheads.

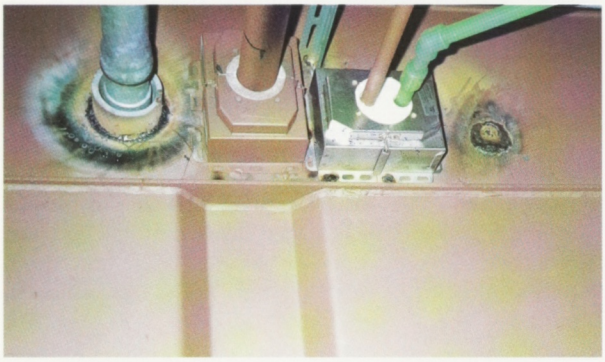


Figure II.10
Geberet bulkhead penetration

The U.S.C.G. noted however that as this type of trap is not closed for smoke until the fire becomes hot enough to operate it and consequently it is necessary to form a seal between the pipe and the trap using polyurethane foam or similar.

Plastic piping has for the time being been excluded from most areas of passenger vessels since it is unable to meet the requirements for flame spread and toxicity.

Vent passages are made using steel sleeves of at least 3mm thick and 900mm in length, which are welded into bulkheads preferably 450 mm each side.In addition when the passage is of an area greater than $0.075m^2$ it is necessary to fit a fire damper. When the passage is less than $0.02m^2$ no additional protection is required. However, in practice, 3mm steel sleeves seem to be universally applied irrespective of area. Where, for compliance with SOLAS II-2 Reg 16, ducting is to be more than 3mm in thickness, this should of course be applied at the ventilation penetrations.

5.1.4 Fire Doors

A-class fire doors can be split into two distinct groups as regards position:

- Doors in Main Vertical Zone (MVZ) bulkheads and stairway enclosures.
- Other A class fire doors.

and three groups by type:

- Self closing doors with hold backs controlled from the bridge or emergency centre.
- Self closing doors normally closed
- Doors normally kept shut.

The doors in stairway enclosures and MVZs are considered to be of particular importance and must be of the self closing type. They should be capable of being closed against an angle of inclination of 3.5 degrees and this should be kept in mind during testing. A large number of fire doors, particularly in passenger areas, are normally kept open with magnetic hold backs which are released from a centralised control position. Hold backs of any other type (such as fusible links) are not permitted.

The closing speed of self closing doors should be controlled by a damper to prevent injury to persons passing through them. In the case of two leaf hinged doors, it is necessary for one leaf to latch first, therefore means should be provided to prevent the passive leaf from closing first.

The requirements for fire doors have been updated in the SOLAS 1992 Amendments to include power operated doors which have become more popular as door sizes have increased. It is interesting to note that doors are now being fitted up to 5.2 metres wide and 6 metres high. An alarm is now required for power operated doors which operates in a similar way to those for watertight doors, sounding 5-10 seconds before the door starts to move. The closing time for the door has been specified as 10-40 seconds. The closing should also be uniform in speed. Power operated doors where fitted should be able to operate 10 times, in the event of a power failure, using locally powered accumulators. Some doors have safety devices which cause the door to reopen on contact with an object in its path. When this is the case, the door should reopen by only 0.75 to 1.0 metres.

Fire doors with hold backs should be closable from both sides and from a centralised control position, i.e. the wheelhouse, and or a central fire station. Doors in the second group, i.e. doors other than those fitted in stair towers or MVZs, may be of the permanently closed type, but hold backs without centralised control are not allowed. These doors should have a sign stating that they should be kept permanently closed if not of the self closing type.

A-class Fire doors fitted in stairways, public spaces, and main vertical zone bulkheads in escape routes, now have to be fitted with a self closing fire hose port of 150 mm square.

Cabin B-15 Class doors, are required to be self closing, including connecting doors between cabins when fitted.
A ventilation opening is permitted in the lower portion of the door up to 0.05 m^2 in size.

Large passenger vessels now have about 600 A-class and 1800 B-class doors, and it is the sheer volume of work which makes testing a time consuming process. It is important that when the doors are tested, especially the self closing type, that the carpet and sole piece, if applicable, are fitted since these can prevent the door closing completely.

Once all the fire doors have been tested individually, a

simultaneous general closing of the doors with hold backs is carried out. This is best done at night when there are only a few people on board. The closing of the doors can be affected by the ventilation system, whether external doors are open or closed, and even the position of the lifts.

A suggested testing schedule is as follows:

1. Inspect the installation welding and identify the doors against certificates.
2. Operate the doors with hold backs locally, using the switch on each side of the door, and simultaneously check the bridge mimic panel.
3. Check the normally closed anti panic type doors.
4. Check the fitting of normally closed doors, including locking arrangements. Doors with locks such as store rooms should not require a key to open them from the inside.
5. In conjunction with the checking of escape routes the door widths, direction of opening, and locks, if applicable, should be checked.
6. Check the interface with the watertight door system and general closing from bridge. (Note that it is almost impossible to get all the doors to close simultaneously). Take note of the doors that haven't closed and investigate why.
7. Check interface with fire detector system if applicable.
8. Check the electrical arrangement, (the door control system should be connected to the transitional source of electrical power to prevent them closing without warning in the case of a black out).

5.1.5 Draught Stops

The importance of draught stops is often misunderstood. They are a vital factor in preventing the spread of smoke and fire in areas where this can not readily be seen. But, perhaps more importantly, they prevent a draught of cold air containing oxygen from feeding a fire in the spaces around which they are fitted. Oxygen is one of the three vital ingredients to sustain fire, the others being a heat source and fuel. A very simple, but effective, means of containment of a fire is to prevent the supply of fresh oxygenated air.

Close fitting draught stops should be fitted 14m apart to divide the air spaces behind ceilings and bulkhead panels.

It is easy to forget to close all the gaps in draught stops, particularly in a vertical sense, between cabin panels. Care should also be taken around stairways which should have draught stops fitted to prevent the effects of a fire being transmitted to all the decks served by the stairs.

Lifts should also be closed around the openings to prevent the passage of smoke and flame between tween decks, and to control draught.

Draught stops are to be made of non combustible materials. An effective method of construction is the use of sheet metal and mineral wool, with the sheet metal being welded to the structure and a gap left above the ceiling which is filled with mineral wool. To fill in small gaps, a certified non combustible mastic is used. Care should be taken when agreeing the design of draught stops to ensure that noise transmission does not become a problem. If there is metal to metal contact, which is not suitably fixed, friction noise and vibration can occur and will be a source of many passenger complaints.

5.1.6 Insulation

A-class divisions are constructed of steel which are then insulated to improve their fire rating from A-0 to A-15, A-30 or A-60 depending on the thickness and density of the attached insulation. Similarly, B-class divisions can be elevated to B-15 by insulation. The numbers here relate to the ability of the insulation to inhibit temperature rise on the non-exposed side for this number of minutes, during a standard fire test. Insulation should be attached as per the specimen in the fire test report, a copy of which should be obtained in all instances where the arrangements are not fully described in the type approval certificate.

Insulation of A-class divisions is generally provided by mineral wool slabs which are attached to the bulkhead or deck by means of steel pins. The spacing of these pins should be no greater than as stated in the fire test report, (normally about 250 mm apart). Pins must be welded to the bulkhead, glued pins are not acceptable. It is important to ensure that there are sufficient pins around the boundaries of the insulation and at any complex structural shapes.

In engine spaces, means should be provided to prevent oil vapours being absorbed into the fibres by using mineral wool slabs covered with an impervious surface finish and taping the joints with glass fibre tape. Around the bilges it is acceptable and indeed desirable, to leave an area about 600 mm high without insulation as this would otherwise soak up oily water and itself become a fire risk.

Problems with insulation usually involve its application. Since it tends to be applied early in the build process, it is subject to damage and is often removed to fit supports for pipes, cable trays and the like (Figure II.11). It is important to ensure that subsequent repairs are correctly carried out using pieces of insulation sufficiently large to cover several pins. The density of the mineral wool used should be carefully controlled as sound insulation using lower density mineral wool may also be in use on board. Overlaps on pipes and other bulkhead penetrations should be 450 mm long, and secured with steel wire, if the fitting of pins is impracticable. Finally, insulation can cover a multitude of sins and careful checking that steelwork is complete, and penetrations are welded should be carried out before insulation work starts, preferably with the pins in place.

B-class bulkhead panels are ordered and delivered in the colour schemes and finishes required by the aesthetic design for the ship. They will have been fire test certified before delivery and, provided no damage has occurred in transit, generally present few problems for survey. There are, however, B-class divisions fabricated on site, either from 3mm thick steel plate, or 1.5 mm sheet steel with 25 mm of mineral wool attached. These provide problems with build quality since they tend to be fitted late in the building process after pipes and cables are fitted. Care must be taken to ensure all joints and openings are effectively sealed.



Figure II.11
Areas requiring insulation repairs

5.1.7 Means of Escape

The Rules regarding means of escape have been completely rewritten in the SOLAS '92 Amendments. The revised paragraph 1.4 of SOLAS II-2 Reg 28, has meant that the layout of passenger ships is now dictated by the arrangement of the corridors, since "A corridor, lobby, or part of a corridor from which there is only one route of escape shall be prohibited". This is without doubt a major step forward in the overall safety of the vessel with respect to passenger evacuation.

The sizing and arrangement of stairways, has been completely changed and, in some cases has resulted in the required openings now being smaller than was previously thought necessary. The approval of escape routes and their widths is carried out at a very early stage in the design because of their effect on the arrangement of cabins and public spaces. So far as survey during construction is concerned, this is a simple process of verification against the approved plans. However, the late addition of doors which have not been shown on the escape plans can cause problems. These should of course be sized as per the other fire doors and open in the direction of escape. Handrails can also cause problems when fitted independently of the stairs and significantly reduce the escape width. No door in an escape route should be lockable in the direction of the escape. Doors to store rooms and similar spaces should always be openable from the inside to prevent people being trapped inside. The only exception is the Brig which necessarily cannot be operable from the inside and should be provided with a key box on the outside. A crew member should be assigned to open it in an emergency. Other matters to check are:

- that the escapes are not impeded by furniture and that bottle necks do not occur.
- that the escape signs and emergency lighting are sufficient and working.
- the widths of escapes and that fire and other doors open in the direction of escape.
- that means are provided to open power operated doors manually in the event of a power failure.

5.1.8 Windows and Side Scuttles

Until the advent of the '92 Amendments, the requirement for A-class integrity did not apply to windows and doors in external bulkheads, nor those in the outer (hull) boundaries. For new ships however, the windows facing lifesaving appliances, embarkation and muster areas, external stairs and open decks used for escape routes, (i.e. category 4 spaces), and windows situated below liferaft (but not lifeboat) and escape slide embarkation areas are to have fire integrity ratings as required in the tables of Regulation 26 of SOLAS II-2. Doors generally need not be fire rated unless they open directly onto the lifeboat embarkation area from an atrium, in which case they must be A-60. A standard window provided with a dedicated sprinkler may be considered as A-0 class. Windows in way of lifeboat lowering areas must be of at least A-0 class. All these matters will be shown on the approved plans but good knowledge of the requirements is essential to deal with late changes to the final arrangement of spaces.

5.1.9 Key Boxes

Some spaces which contain safety equipment need to be locked to prevent theft or misuse. In order that the equipment inside is readily available the USCG require a key to be placed in a box with a glass front. Although there is no written SOLAS requirement for these, they make good sense particularly for the following spaces:

- door operating stations
- CO2 Room
- Battery Room
- Closed spaces in the accommodation with fire hoses inside
- Fire lockers and stations
- Emergency generator room

5.2 Active Systems

5.2.1 Sprinklers

All ships now have to be provided with a sprinkler system which should be full of water and ready for immediate use so that no action is required on the part of the crew to set them in motion.

Traditional systems are normally charged by means of a pressure tank which should be located in a non sprinklered area remote from Category A spaces. This tank must be capable of holding 2800 litres and be filled with 1400 litres of fresh water which is pressurised by air, to keep a head in the pipe-work. This then supplies water to the individual sprinkler stations arranged around the ship. Each of these stations should not supply more than one main vertical zone or two decks. The sprinkler tank ensures that the system of piping (which is now thin wall stainless steel up to diameters of 80 mm), is filled with freshwater rendering an accidental discharge of water less catastrophic, and the pipe-work less damaged by corrosion.

Upon discharge from a sprinkler head, the water level in the tank and the pressure begin to drop triggering a dedicated sea water pump supplied from the main and emergency sources of power to come into operation. This supply bypasses the tank and provides a continuous supply of water to the system. Where possible, means should be provided to run this pump for an extended period so as it can be regularly tested by the ships crew.

The individual sprinkler stations are provided with a pressure switch which activates an alarm in the case of flow across the non-return valve provided in each case. In addition, it is possible to find flow switches in the pipe-work which help to identify more precisely the area in which the sprinkler has been activated, particularly in ships built before the advent of smoke detectors in every space.

Whilst they are not a requirement, it is in everyone's interest that flushing valves are fitted at the end of branch lines. When installation of the system is complete it should be flushed through with fresh water in order to ensure that the piping is full and that the alarms are functioning correctly. Thin wall stainless steel piping should be maintained full of water to ensure protection of the rubber seals in the joints. It is important to ensure that cleanliness of the piping is maintained during fitting, since contamination of the stainless steel by stagnant dirty water can lead to corrosion. All tools used for cutting and grinding should be dedicated for stainless steel and not used for cutting mild steel fitments such as pipe hangers.

A crossover valve between the sprinkler system and fire main should be provided and clearly marked. This valve should be a screw down non-return valve, but in practice a certified butterfly valve (which has been the subject of a fire test) and non return valve may be fitted. Towards the completion of the vessel when the sprinkler system and the fire main are installed, it is good practice to supply the fire main with fresh water from the town supply and open the cross over to the sprinkler system so that the system is pressurised. This provides sprinkler protection with relatively harmless fresh water during a high fire risk period in a ships life. It also allows any 'bugs' in the system to be ironed out before the ship leaves the yard.

The sprinkler system is generally connected to the fire detection system and will initiate alarms and consequent actions, such as closing fire doors etc.

There are certain areas on a ship where accidental discharge of a sprinkler system could cause damage to essential electronic communication and control systems. Typically, such spaces are the bridge and radio room. The effect of spurious discharge in these spaces is more serious than the risk of an undetected fire and it is accepted that the sprinkler branch protecting them need not be pressurised with water, ie. a dry pipe system. The control valves for these systems should be located immediately outside the door to the space protected and double valves fitted. The valves and any access hatches should be labelled and the valves marked on the fire control plan. As extra protection against an accidental release of water, normal bulb type heads should be fitted. The fire rating for division of these spaces has always been considered using the unsprinklered values, in the tables of SOLAS II-2 Reg 26, which has consequences for the decks in the case of category 1 spaces. However, the SOLAS '92 amendments assume that sprinklers are fitted everywhere and the higher insulation values of the previous regulations have disappeared.

A spray pattern diagram which will describe the area covered by each sprinkler should be obtained. Generally, this will be in excess of two metres in radius. Typically, a maximum of two metres is used as the distance from bulkheads and four metres as the greatest distance between heads for sprinkler spacing.

For public spaces, where ceilings are often stepped or of unusual design, it is difficult to decide whether the coverage will be sufficient until the ceiling has been erected. There are often objections on the part of the Architects to the location of sprinklers when the ceiling is of a particular design , such as mirrored or with special light fittings, and special care needs to be taken with the sprinkler positioning to satisfy the designers aesthetic concept whilst maintaining adequate coverage. It is interesting to note that the present water quantities of 5 litres/min/m^2 were derived from fire tests of a cabin constructed in 1939 with the wooden materials for panelling and furniture in use at that time. This application rate is probably generous in view of modern construction methods and materials. Figure II.12.

It can be seen that the approved schematic drawings are only a guide and that the positioning of heads should be carefully considered on a case by case basis. In this the Surveyor has been greatly helped of late by the introduction of press fitting stainless steel piping. This is both light and flexible in terms of fitting, and allows the Surveyor to



Figure II.12
Sprinkler heads located to suit ceiling design

request modifications which can be carried out on the spot quickly and easily.

Three types of sprinkler head are in general use. Open heads which are used in dry pipe systems, high temperature heads for Galleys, (particularly where the opening of an oven door can cause a sudden blast of heat), Saunas, Steam Rooms, Laundries and other hot spaces, and standard heads used in other spaces. The use of high temperature heads should be restricted as much as possible since it is important that the system comes into operation quickly.

Check that piping does not run outside the accommodation or that where it does, it is sufficiently protected from frost. During building sprinkler heads often become contaminated with paint. This should be carefully cleaned off or the head replaced.

Testing will take place over an extended period as fitting out progresses.

- Pressure test and check the position of the heads. This is usually done station by station.
- Pressure test the main, between the stations and the tank. Check that all the necessary valves are fitted
- Test the tank system, alarms and valves. Check that the pump operates satisfactorily by dropping pressure in the holding tank, using the test valve
- Test the station alarms using a pressure drop at the station (the valve will activate with a differential across the station valve of about 1 bar.) and manually, using the test switch. Ensure the alarms operate correctly on the bridge
- Flush the system through using fresh water, to ensure that the piping is full of water and that the alarms operate correctly, including any flow alarms.
- Finally check sprinkler station valves are locked open, and closed in the case of the Sprinkler/Fire main crossover and pressure tank. Ensure that the keys are with the Chief Officer and that the correct instructions are posted at each station.
- Verify that spare heads have been supplied.

5.2.2 Fire Alarms and Public Address Systems

Modern practice is to fit a combined public address (P.A.) and fire alarm system. The fire alarm, general alarm and crew call are all sounded through the P.A. system with an alarm tone produced by means of a signal generator. Despite care being taken to differentiate between alarm signals it would seem that passengers are often unable to distinguish between alarms and assume that there is a boat drill even in the case of a fire alarm! The sounding of the alarm tone may be more onerous than making announcements or playing music and during testing it is important to check that the system can operate for extended periods without overheating. The public address system or other effective means of communication is to be available throughout the accommodation and service spaces and control stations.

The following is the testing procedure:

- Check the loudspeaker specification. Ensure that short circuit isolation is fitted to each speaker type.
- Check each speaker individually to ensure that it is working correctly and that it is connected to the correct circuit. Different circuits work in different areas. (i.e. crew working areas, passenger accommodation areas, machinery spaces etc.), so that crew can be addressed without alarming the passengers unnecessarily.
- Check that where volume controls are fitted, they are overridden by safety announcements.
- Check that where the system is used to play music (such

as in the Theatre and Disco) that the music is overridden by an alarm or announcement.

- Check that the Master call points are given priority over all the others if several are fitted.
- Check the interface with the fire detection system (for stopping fans and closing fire doors) and that the fire alarm is sounded through the accommodation if the alarm is not responded to within two minutes
- Check that the fire alarm is made by a switch and not a push button, (From October 1997.) and that a second alarm point is fitted
- Check the sound power levels for the fire alarm with the fire and watertight doors closed

With respect to the audibility of alarms, the measurement of sound is a complex subject and worth looking at briefly in order to understand the requirements. Sound is measured in decibels (dB) which is a logarithmic scale. There are different measurement criteria within the dB scale based on frequency. The scale used in the Code on Alarms is the dB(A) scale which deals with sound in the audible frequency band. Sound meters will have a selector for the scale (A, B or C) and the correct scale should be used since the sounds outside the frequency band selected are filtered out. At most frequencies, "A" weighting will give a lower reading than that for "B" or "C".

To give an idea of sound levels, two people speaking normally will register about 65 dB, speaking loudly they will register about 75 dB. The maximum sound level one could expect to hear on a ship would be in the Engine Room where the sound level next to an engine will be about 120 dB(A). However to hear an alarm in an engine room where the background noise level is 120 dB does not require an alarm of 121 dB since the alarm will be operating at a different frequency. Sound power levels should be checked using a meter.

The code on alarms and indicators (Resolution A686(17)) has now laid down specific requirements for sound power levels on ships. These state that alarms should produce sound pressure levels of 75 dB(A) at the sleeping position in the cabins and at two metres from the source and at least 10 dB(A) above the ambient noise levels. In no case should sound power levels exceed 120 dB(A). Maximum ambient noise levels will probably be written into the contract by the owner and, in the accommodation spaces of a modern vessel, they will be around 65 dB(A) as a maximum. At the stern it is possible that these values may be exceeded. The Shipyard will probably be obliged to take noise levels during the sea trial but, if not, this will need to be arranged.

The specification of recent new buildings has required a drop in sound level across the cabin bulkhead into the corridor of 30 dB, hence to arrive at 75 dB(A) at the sleeping position 105 dB must be achieved in the corridor which is approaching pain levels for the human ear. Consequently the fire alarm system will probably have to be routed into each of the cabins. It will no longer be sufficient to fit speakers only in the corridor and consideration must be given to this at the planning stage.

On some ships the P.A. system has been routed through the entertainment system in the cabins, one channel being provided for announcements. Unfortunately these systems are of limited use from the safety aspect since they are not connected to the emergency source of power.

5.2.3 Fire Detection System

Recent changes in the regulations have meant that all new buildings have smoke detectors fitted in addition to the sprinkler system. Smoke detectors now generally have addressable heads. Each unit is given an individual code which, in the event of an alarm, is decoded at the central alarm panel to give the deck, zone and a descriptive text describing the location of the head. This descriptive text is very important for operational reasons and, if possible, each one should be checked individually and amended as necessary to avoid any confusion.

The '92 amendments to SOLAS have a number of important new requirements. Regulation 13, para 1.15 requires that the loops are arranged such that they cannot be damaged at more than one point by a fire. It is assumed that the fire would be localised, since the loss of a complete fire zone would render the loop in that zone and adjacent zones useless. Systems without addressable heads are permitted, but restrictions on the extent of their coverage are such that a large number of loops would have to be fitted.

Detector heads are now available with combined heat and smoke sensors. These are particularly useful in areas with high air flows which tend to carry away the smoke before it has a chance to activate the detector. Flame detectors are normally fitted over engines and in the purifier flat where there is high risk of an oil fire. It has been noted during the testing of systems that flame detectors draw a considerably higher current than smoke detectors and consequently the number that can be accommodated on a loop is restricted.

The latest vessels have the fire detection system interfaced with a computer display which automatically produces a plan of the zone where the alarm was activated.

Testing the system is a simple if time consuming and monotonous job. A ship of 50,000 gross tons will have about 2,600 smoke, flame and heat detectors and push button alarms. Assuming all goes well, the testing should take about 40 hours in total and it is important to test them all. It has been found that the sprays available for testing smoke detectors tend to linger and consequently it takes a long time for the head to reset, (note that sometimes the head will fail to reset, which indicates as a fault at the control panel).

The smoke detector location plans are of course approved, but these provide only a guide. Often non-fire-rated bulkheads have not been shown and consequently a large number of detectors have to be added. In particular, beware of spaces marked on the drawing as "void". Since the crew are always short of space they will adapt these spaces to stores, as necessary. This also has implications for the structural fire protection. Checks on such spaces should be as late as possible before delivery. The maximum distance between heads is 11m for smoke and 9m for heat detectors. The maximum floor area is $37m^2$ for heat and $74m^2$ for smoke. As a general rule all spaces that are bounded by A or B class divisions are provided with a smoke detector,

irrespective of whether the door is held open with a magnetic hold back or not.

When testing the system it is worth bearing in mind that it should be capable of showing the spread of fire. Testing could proceed as follows:

- Check the control panel to ensure that there are no faults on the loop.
- Put all the heads and alarm calls in the loop in alarm individually and one by one, taking note of the order. At the same time check the position of the heads.
- Check the order in which the alarms were activated against the alarm print out.
- Check the addresses.
- Check the operation of the alarm panel, interface with fire alarm and fire doors closing, vent fan stop, power supplies and fault alarms.
- Ask the yard to keep the alarm system switched on for some time to allow the system to settle down and any faults to come out.
- Ensure spares are provided.

5.2.4 CO_2 Systems

Machinery spaces of Category A are required to have a fixed fire extinguishing medium and this is normally CO_2. In addition, the '92 Amendments require that the exhaust systems from galley ranges are provided with a fixed system for extinguishing fire within a duct. CO_2 smothering may also be found in a number of other auxiliary machinery spaces.

The amount of CO_2 carried is related to the volume of the largest space to be protected. A system of bottle banks is connected to a manifold fitted with remotely operated valves, the same CO_2 being allocated to different spaces as required.

The CO_2 system for machinery spaces has been developed to the point whereby it can initiate the stopping of diesels, vent fans and pumps, and close dampers, watertight doors, and fire doors. This has decreased the amount of thinking to be done by the crew, but greatly increased the amount of testing and checking to be done by the Surveyor.

The amount of CO_2 and size of piping should be as per the approved plan. Unless the manufacturers certificates of test can be produced, 10% of the piping should be tested in the shop to at least 125 bar. The manifold for the system is tested to 190 bar. The piping from the manifold to the point where it enters the protected space should be tested for leaks, but testing the piping in the protected space itself is time consuming and unnecessary since any small leaks are insignificant and any major leaks can be seen immediately since the system will not hold the test pressure. After testing, blow through to 20 bar to remove any foreign particles or water.

All pipe-work should be labelled to indicate the space it serves. It should be ensured that the piping is dried after testing since the release of CO_2 causes rapid cooling which can freeze any moisture and, potentially, block pipes. For this reason avoid water traps during fitting which can allow water to accumulate. Where this is not possible, a short run off piece with a drain plug should be fitted at the lowest point.

Nozzles should not be placed over escape ways or ladders, to allow ease of evacuation of the space. Pipework joints may be flanged or of the barrel type. Running couplings are not allowed. Relief valves, which vent to the atmosphere, should be fitted in the system and care should be taken with the location of the vents to ensure that gas is not drawn back into other ventilation intakes.

Final testing of the system is a long process which needs to be done with care and in a logical manner. It is best split into two parts, testing of the pipe-work and testing of the electrical system.

Testing of the Pipework

The bottles are disconnected from the manifold for the testing to prevent an accidental discharge, and a small CO_2 bottle attached.

It has been found that unless the relatively high pressure of CO_2 or nitrogen is used, the system may fail to operate properly. In particular, the non return valves may block the passage of the gas.

Since the system will have to be tested during the ships life and for the USCG at the initial control verification survey, it may be useful to fit a permanent test facility.

- Check that the time delay operates correctly when release of CO_2 is simulated from the pilot cylinders (45 seconds). It should be possible for either of the pilot bottles to operate the system independently .
- Check that the correct co-pilot bottles are activated and that these in turn open the correct number of bottles for a given space.
- Check that the correct directional valve operates.
- Check that any safety discharge pipes from the system do not pass near to ventilation intakes.

It is most important to ensure that if bursting discs have been fitted, they are removed or isolated for any testing, including blow through, since repeated testing at low pressure will cause them to rupture at well below their rated pressure.

Testing of the Electrical System

The system will probably be connected to the automation system to stop the engines and ventilation fans in the space protected, and to close the fire and water-tight doors. The problems involved with testing the system tend to be logistical since the closing of doors without warning can be dangerous.

- Check that all the fans, pumps, engines for the space are running and that the doors and dampers are open.
- Check that the correct items close/stop as required.
- Check that it is not possible to restart the fans until the CO_2 system has been reset.
- Check that the audible and visual alarms work. (The audible alarm should be distinguishable from other alarms).
- Check that the correct instructions are posted and that there is an operating manual showing how the system functions.

In addition, the alarms must be tested on the bridge and in the engine control room together with the audible and visual alarms in the protected space.

Finally check that the CO_2 storage space has sufficient ventilation and that the door opens outward. Bottles should be carefully fixed so that they cannot rotate. Lighting should be connected to both the main and emergency systems. There should be clear instructions posted detailing how the system works.

5.2.5 Ventilation System

Checking and verifying the ventilation system, is one of the most difficult tasks to be carried out during the construction of the vessel. Approval of drawings is particularly difficult since the system is built in three dimensions and, above all others, tends to be badly represented at the planning stage. The three dimensional problem also exists at the survey stage since checking the system involves much climbing of stairs, in particular for the stair towers and control stations, to ensure compliance with the requirement that these systems are completely independent in each main vertical zone. The requirements for vent systems are specified in SOLAS Chap II-2 Regulations 16 and 32 and there is also a paragraph of note with implications for the CO_2 system in Reg 5. para 1.4.

Dampers are fitted for various reasons. These are:

- Dampers for the closure of spaces prior to the release of CO2 gas fire extinguishing systems.
- Fire dampers to maintain the integrity of fire bulkheads.
- External dampers to the main inlets and outlets of the vent system to prevent the ingress of fresh air to a fire.
- Smoke dampers to prevent the passage of smoke from one deck level to another.

Where dampers are fitted behind ceilings or panel systems access will be required for testing and maintenance purposes.

Ensuring compliance of the ventilation system with the Rules involves checking that the requirements for structural fire protection and prevention of the passage of smoke are met. The Regulations can be simplified into the following parts and checked individually. Particular attention should be paid to Control Stations, Machinery Spaces, Galleys and Stair Towers.

In main vertical fire zone divisions an automatic fail safe fire damper is to be fitted irrespective of the size of duct. For ventilation from machinery spaces of category A or galleys passing through accommodation spaces, service spaces or control stations, a steel ducting penetration is to be fitted with a fire damper close to the boundary. In addition, A-60 insulation should be fitted for 5m along the length of the ducting measured from the damper. Alternatively the fire damper may be omitted if the ductings is insulated to A-60 standard along its entire length. For galleys the requirements for dampers are applicable to both the extraction and induction sides of the ventilation system. Ventilation from accommodation spaces which passes through machinery spaces or galleys is dealt with in the same way as machinery space ventilation passing through accommodation. Note that ventilation of Machinery spaces and galleys should not serve accommodation spaces and vice versa.

Ventilation which connects decks should be avoided or have smoke dampers fitted. One system now being fitted involves the fire detection system. The smoke detectors are linked to the ventilation system and, in the event of an alarm, the relevant vent fan in the A.C. station is stopped automatically. This is interfaced with the fire damper which then closes. The loss of draught causes the gravity dampers to close at each level thus preventing the passage of smoke between decks.

Galley fires are a major source of concern on passenger vessels and galley ranges are now required to have a grease trap above them to prevent excess grease passing into the ducting and causing a fire risk. A damper system is also incorporated above the ranges such that in the event of a fire the ducting can be isolated and CO_2 introduced. Controls for the release of the CO_2 should be arranged outside the galley. Means to isolate the electrical supply to the galley ranges should be provided. In current newbuildings a washing facility is included with the hood. Means to inspect and clean inside the ducting should also be provided.

Control Stations are required to have two alternative and separate means of air supply. In cases where the Control Station is adjacent to an open deck it is acceptable, subject to the approval of the administration, for one of these means to be an opening door or window. However It is necessary to prevent the passage of smoke into the space, and smoke dampers are required on ventilation ducting. Vent intakes from the two sources should be as widely separated as possible to avoid them drawing the same smoke in the event of fire.

To enable safe evacuation from all spaces on a ship it is now necessary for stair towers to have an independent fan and duct system that is completely isolated from all other spaces. Special requirements are also applicable to atriums. Extraction fans which come into operation with the smoke detector system must be capable of clearing the space of smoke in 10 minutes. This system must be tested using a smoke generator in order to prove its adequacy.

5.2.6 Ventilation Controls

SOLAS II-2 Regulation 32 Para 1.6 requires that all power ventilation, shall be fitted with controls so grouped that all the fans may be stopped from either of two separate positions, which shall be fitted as far apart as possible. In practice these two separate positions will probably be the wheelhouse and the Engine Control Room.

There has been much discussion regarding the relative merits of leaving the extraction running in the corridors and cabin areas and the supply in the stair towers, thus helping to clear smoke and maintain a positive pressure in the stairway to prevent smoke entering. However, it should always be remembered that there is a risk of drawing in smoke from the outside.

Some fans are interfaced with dampers to prevent damage to the system if the damper is closed, and to simplify the

operation of the safety stops. The switches for ventilation are grouped by fire zone in the case of the accommodation and by engine space in the case of the Machinery Spaces. There is no doubt that in the near future there will be some interesting developments in the field of smoke control involving automatic logic control. Testing and approving these proposed automated systems will require careful consideration.

5.2.7 Fire Pumps and Fire Main

Passenger ships greater than 4000 gross tons or over are required to have at least 3 fire pumps. These should be arranged such that a fire in any one space will not put all the pumps out of action. In practice this means that at least one of the pumps will be supplied from the main and emergency switchboard and located in a separate space from the others. Cabling from the emergency source of power should not be led through galleys, Category A machinery spaces, or other high risk spaces.

The minimum pressure to be produced with two fire pumps running and hoses delivering $140m^3/h$ of water is to be $0.4N/mm^2$. In addition, each of the pumps should be capable of producing two jets of water of 12m from the most onerously placed hydrants. Displacement pumps should be provided with relief valves. Rotary pumps are protected by the performance curve of the pump. Centrifugal pumps should have a non-return valve fitted in the line to the fire main.The fire main on a passenger ship is always pressurised, for which purpose a small topping pump and compensation tank are fitted. In the event of a pressure drop, which the topping pump cannot maintain, the main fire pump should automatically activate. For ships with a UMS notation, a switch to start the pump manually should be provided at the bridge, as should a means to show that the pump is running.

Where muff type couplings are used instead of traditional flanged joints, it is most important that these are well supported by pipe hangers, particularly at elbows, to avoid them bursting. Fire hoses and nozzles outside of the engine spaces, should be permanently attached and ready for immediate use. Valves should be fitted to enable the fire pumps to be isolated from outside the space protected. Pipes passing back into the space should also have isolating valves. These valves should be clearly labelled and painted red.

The fire main should be tested to 1.5 times the working pressure, which will be about 8 bar.

- Pressure test the piping and position of the hydrants against the approved plans.
- Check that there is water to each hydrant.
- Check that the pump starts when there is a drop in pressure.
- Check the pressure with two hoses producing water in the most onerous position for each of the pumps in turn.
- Check the remote starting from the bridge.
- Check that the hoses are fitted and that they are the correct length and diameter. Tools should be available. Nozzles should be of the jet spray type with shut off.
- Check that the international fire hose connections are provided and the US Fire Dept standard connection, if required.

5.2.8 Emergency Source of Electrical Power

SOLAS requires that ships are provided with a self contained source of electrical power, the arrangement and testing of which is not discussed in this paper. However, the items connected to it are of interest. There are also implications for the structural fire protection since the space containing the emergency source of power, transitional source and any transformers should not be contiguous with machinery spaces of Category A, transformer or switchboard rooms associated with the main source of electrical power. In other words, no boundary of these spaces can touch the boundary of spaces such as the engine casing.

The emergency source of power may be a generator or batteries. However, on a large modern vessel the amount of power required, and length of time that services must be provided, will probably dictate that this will be a diesel generator of around 800 kW.

In addition to the emergency generator, a transitional battery source of power is fitted. This provides power to certain essential services until the emergency generator comes into operation. In particular, lighting is provided and the fire doors hold-back system is supplied, to prevent closing of the doors.

The Emergency generator is required to power the following:

- Emergency lighting.
- Navigation lights
- Radio station (GMDSS).
- Internal communication systems.
- Bridge equipment required by SOLAS V/12 (rudder angle indicator, gyro radar etc.).
- Fire alarm and fire detection system.
- Ships whistle.
- One of the ships fire pumps.
- The sprinkler pump.
- The emergency bilge pump.
- The steering gear (subject to certain conditions)
- The W.T. doors, with the indicators and warning lights.
- The lift cars (to bring them to a safe position).
- Stabilisers (to house them).

In addition emergency power may be required for other items such as control station and stairway ventilation, lifeboat davit pumps etc.

The transitional source is required to supply for half an hour:

- The emergency lighting
- The fire detection system and fire alarm
- The ships whistle
- All internal communication equipment required in an emergency.
- W.T. door control and alarm systems.
- Fire door hold back and release mechanisms.

It should be verified that all these services are available from their required source of power.

5.2.9 Emergency Lighting

Spaces required to have emergency lighting are:

- Muster and embarkation stations.
- Alleyways stairways and exits onto muster and embarkation stations.Service and accommodation alleyways, stairways and exits and personnel lift cars.
- Machinery spaces and generating stations.
- Control stations and machinery control rooms, main and emergency switchboards.
- Stowage position for fireman's outfits.
- The steering gear.
- At the fire pump, bilge pump and steering pump and at the starters for these motors.

As can be seen, virtually all spaces excluding lockers, cabins and sanitary spaces are included in the above. Testing the system presents a number of problems in that the amount of light required is subjective and logistical problems exist since the lighting can only be tested as the vessel nears completion and the batteries can only be discharged for 30 minutes at a time. Testing should be carried out with the fire doors closed in order to ensure that all corridor spaces are illuminated.

6 Other Statutory Items

6.1 Testing of Lifts

Modern Passenger vessels have a large number of lifts and testing them takes considerable time. SOLAS requires that all lift cars can be brought to deck level for the escape of persons, using the emergency source of power. This may be done sequentially.

When testing and examining the lifts the following should be verified:

- Only pipes and cables pertaining to the lift should be run in the lift trunk.
- The lift should be arranged to prevent persons falling between the lift and the trunk.
- The trunk is to be ventilated by an independent system.
- The trunk entrance is to incorporate an area of non slip material and should prevent the ingress of water.
- Crew lifts are to incorporate a hatch at the top of at least 0.5 x 0.5 m .
- A device is to be fitted to support the counterweight in the case of rope failure.
- Crew lifts are to have a ladder throughout the shaft.
- Passenger lifts are to have a hatchway that can only be opened from the outside. Ladders should be available to take passengers to the nearest landing.
- An escape hatch should be provided at the top of the crew lift trunk. It should only be possible to open this from the outside, using a special key kept in a box by the hatch.
- Emergency notices should be provided in and on the lift and in the lift trunk.

6.1.1 Lift Alarms and Safeguards

- Interlocks are to be provided to prevent operation of the lift when shaft access doors are open.
- In addition to upper and lower landing stop controls, means are to be provided to prevent overrun on upper and lower ends of run.
- Lifts are to be arranged such that they automatically stop at a deck in the event of a power failure.
- A safety device is to be provided in the event of over-speed or of slack ropes or rope failure.
- Means are to be provided to prevent the use of the lift with the escape hatch open. An interlock is to be fitted to prevent accidental closure restarting the lift.
- A phone or alarm is to be provided.
- A landing indicator is to be provided inside and outside the car.
- Means are to be provided to raise or lower the car manually.
- Automatic emergency lighting is to be provided in the car motor room, car and trunk.

When testing the lifts, a complete round trip is to be completed with 1.1 x the applied or rated load. The brake should hold with 1.25 x the rated load in a static test. In addition:

- Check that the structure is fitted in accordance with the approved plan.
- Check the normal operational functions of the lift.
- Check that draught stops are fitted around the openings.
- Check that the doors have the correct fire rating.
- Witness the overload tests.

- Check that the emergency notices are fitted in the trunk.
- Ensure that the lift stops at a deck in the case of a blackout

6.2 Inclining test

Assistance with the inclining test is normally given from Headquarters. The procedure for carrying out an inclining test is given in the Marine Division Survey Procedures Manual.

The problems associated with the inclining test of a large passenger vessel tend to be logistical. There are a large number of tanks and bilge spaces which have to be dried out. For this reason alone, it is preferable to carry out the test immediately after the ship has left the dry dock where the drain plugs will have been removed from the tanks to completely dry them.

Since it is necessary to have the approved stability manual on board before a passenger Safety Certificate can be issued, the inclining test has to be carried out about one month before completion of the vessel to allow time for the book to be prepared and approved. This will in turn mean that the vessel will probably be less than complete with respect to the owners outfit, in particular, televisions, phones, art work etc. may not be on board. Consequently the weights on and off lists tend to be quite long and preparing them can take several days.

The inclining test itself presents no particular problems. The lift shafts provide good positions for long pendulums and weight transfer, if necessary, can be effected using water in the heeling tanks or similar spaces.

6.3 Sea Trials

Very little needs to be seen during the sea trials other than the engine items, however the following must be tested:
- Steering Gear
- Compass calibration
- RDF and other electrical bridge equipment.

This may be the only chance to test the lifeboat davits on the side which the ship normally moors against the quay and these boats should be lowered to the water.

The engine room smoke detectors should be tested with the vessel underway and the fans running.

Sound power level checks for background noise will need to be taken in order that they can be compared against the values taken for the fire alarm.

6.4 Load line

The Load Line for a passenger vessel presents no particular problems, indeed some areas of the C11(IMO) such as Cargo Hatchways will be not applicable thus making it simpler than for a cargo vessel. Other areas such as overboard discharges and cargo ports and other similar openings require more attention than normal. Since a damage stability assessment is carried out, the air pipes on the open deck should be above the damage waterplane.

The freeboard for these vessels will be calculated on the basis of a subdivision draught and the vessel is assigned a 'C' mark. When fixing the marks on the side of the vessel it has been found easier to fix the Load Line mark, by measuring up from the bottom, to be sure that the mark is fixed at the correct draught, and then to measure up and fix the deck line using the tabular freeboard. This ensures that the Load Line mark is exactly in the correct position. Any discrepancy with the actual deck line should of course be investigated.

The location of freeing ports can be a cause for concern and should be discussed with the owner, who may ask for them to be sited in a particular area so as not to disturb the ships profile. The number of overboard discharges below or around the waterline can be considerable and it is useful to ask for an overboard discharge profile plan to be produced. The discharges can then be easily seen in the dry-dock and identified against the drawing before locating them on the inside and checking that the correct type of valve and pipe are fitted.

The definition of Position 1, being the area within 0.25L of forward, becomes a problem when applied to passenger vessels. Modern vessels tend to have the accommodation extended further forward so as to maximise the amount of enclosed space. This results in a number of doors being located in the Position 1 area, some of which may be escapes. These cases should be referred to the plan approval office for special approval. Enclosed mooring decks forward can also present problems since the degree to which they are enclosed will determine the need for freeing ports, scuppers and coamings on any hatches and doors. Where an ash or bottle chute is fitted below the waterline two valves should be fitted with an interlock to prevent them being opened simultaneously.

6.5 Plans

The fire control plan should be in accordance with the requirements of Resolution A756(18) and should be approved and stamped before the Passenger Safety Certificate is issued.Symbols should be in accordance with Resolution A654(16). This always causes problems from the point of view of time, since it is difficult to include all the amendments which will be found necessary towards completion of the ship, especially when colour is used. The drawings should include a profile and a place to note any future amendments. The other plans which need to be approved and posted on board are the Lifesaving and Damage Control Plans. The muster list must also be sent to London for approval well in advance of the vessels departure.

7 USCG Visit

Before any vessel can embark passengers in a US port it must undergo an Initial Control Verification Survey (ICVS) by the USCG. This survey is now normally carried out in the Shipyard just before the vessels departure. This has various benefits to the builder who can make good any problems in the yard, and to the owner who will avoid any problems in the United States and can thus put his ship directly into service.

The ICVS is a thorough check of the fire protection and lifesaving appliances. Considerable time is spent checking documentation and certification, particularly of materials used in the outfit, which should be prepared in advance by the yard. A fire and boat drill may be carried out if the crew are available and trained, although this may have to be deferred to the first port of call in the US. It is most important that the survey runs smoothly and is well organised. It should be borne in mind that a number of the more important safety items may have been checked some months beforehand and, consequently, may need to be rechecked, especially if no maintenance has been carried out meantime. The lifeboats should be swung out and lowered, the sprinkler stations, CO_2 fire dampers, fire pumps, fire doors and smoke detectors checked.

The USCG will have a different perspective to those involved in the construction and their visit is a valuable contribution to the vessels overall safety. In particular, there is a tendency when seeing the same spaces day in and day out to become familiar with the layout of the ship which makes it difficult to assess the clarity of the escape route signs, or any items that may impede the escape routes. However, the co-operation agreement between LR and the USCG referred to in Part I of this paper should enable proper preparation by all concerned and a straightforward control inspection to be carried out.

8 Passenger Ship Safety Survey

Whilst most of the items for the Passenger Ship Safety Survey will have been covered under continuous survey, there will be a number of loose items which cannot be fitted until the last moment for fear of theft or damage, (such as Lifeboat equipment, EPIRBS, lifebuoys etc.), or are Owners supply (such as charts, books and nautical publications) or simply because they are the last items to be fitted (such as plans, signs, fire extinguishers etc.). Items which have not been mentioned elsewhere in the text but which should be checked are:

- Charts, books and nautical publications.
- Navigation Lights and signalling. Check the power supplies and positions. Sidelight boxes should be painted black, and screened so that they cannot be seen across the bows. Spare bulbs should be provided. The aft masthead light may have to be fitted on an extendible mast to fully comply with the Regulations.
- Bell, gong and shapes, with certificates, copies of which should be retained.
- Bridge equipment: This can be done by the radio engineer, or the crew. The RDF and compasses should already have been swung on the sea trials.
- Pilot Ladder.
- Accommodation ladder.
- Lifeboat embarkation ladder; check that they are of sufficient length.
- Distress signals (12 Parachute rockets) and line throwing apparatus (4 sets).
- VHF radios for the watchman and fire squad with charging arrangements.
- Safety plans are posted and up to date, including copies in canisters outside the accommodation. There should be a set of these on the bridge wings.
- Fire fighting equipment, breathing apparatus, fireman's outfits, long handled axes, and water fog applicators.
- Survival aids: Immersion suites, lifeboat equipment and food, lifebuoys, lifejackets, and liferafts (which must be SOLAS A Pack and all davit launchable). Since some of the above have expiry dates their arrival into the shipyard is normally delayed until the last moment.
- Signs and Labels: These are a most important item and, with good reason, are a particular favourite of the USCG, perhaps because they tend to be given a low priority. See IMO Resolution MSC/Circ 617, Guidelines on Passenger Safety Instructions for signs on the back of cabin doors which should be discussed and agreed with the builder early on. Any isolating valves for sprinklers and fire main should be clearly marked, as should the crossover valve. Instructions should be posted at sprinkler stations, remote stops for fuel tank valves, galley range isolating switches and the CO_2 system.
- Escapes and Muster stations should be clearly marked with the SOLAS symbols and be unambiguous.
- Spare Parts are required for various items including lighting, sprinkler heads, smoke detector heads and fire extinguishers.

9 Final Comments

The issue of certificates on delivery of a passenger ship is the culmination of a design appraisal and construction process over an extended period. Whilst this is an end point for the surveyors in the construction port, it is just the beginning for the field surveyors in the area where the ship will operate. It is important to Lloyd's register that the Owner has a successful ship and is able to operate cruise schedules in the most effective way. This will involve close liaison between LR and the Owner in the planning and approval of modifications which will invariably be required, not least from the retrospective application of new statutory regulations. Routine surveys also have to be carefully planned and it is often necessary to assist in the maintenance of cruise schedules by carrying out some, or all, of these surveys at sea.

The Passenger Ship Safety Certificate is issued with a validity of twelve months, therefore a full renewal survey is required each year. The number of surveyors involved in the activities described in Parts I and II of this paper are small but the potential exists for many more field surveyors to be involved in Renewal Surveys. For this reason Part III of this paper is more detailed in the level of survey guidance given.

Part III

Passenger Ship Safety Renewal Surveys

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Appendix A – Schedule and Remarks of the Passenger Ship Safety Survey
Appendix B – Masters Questionnaire

1 The Surveyor

The Surveyor(s), should be authorised for this type of survey and should have experience, training and sufficient knowledge of the applicable regulations.

A list of Surveyors authorised to carry out passenger ship safety surveys is maintained in Headquarters (CSD/SAS/PASS).

Surveyors should also have:

- The right attitude for this type of survey, which includes an understanding of the passenger ship and cruise industry, bearing in mind that a passenger has the right to expect the same level of safety on an old passenger ro-ro vessel as a modern cruise ship.
- Necessary communication skills, interpersonal skills and the ability to work with the ships staff, to achieve with their co-operation, a high level of safety as common goal.
- A good deal of self-confidence based upon a sound knowledge of the regulations.
- A good physical condition to walk long distances around the vessel and climb numerous flights of stairs in the course of a working day.

2 Preparation for the Survey

After the survey request has been received, it shall be established whether Lloyd's Register has been authorised by the flag state administration to carry out the survey. If in doubt, London office (CSD/SAS/PASS) should be consulted.

The ship must be classed with Lloyd's Register. For any other Lloyd's Register classed vessels, registered under flags for which LR is not authorised to carry out the passenger ship safety survey, written authorisation and instructions shall be obtained from the flag state administration, via London office (CSD/SAS/PASS) before the survey is commenced.

Documents to be collected prior to the survey are:
Copies of previously issued: (applicable to North America only, for surveys outside of this area London office (CSD/SAS/PASS) should be consulted).

Passenger Ship Safety Certificate.
Form 2114, record of passenger ship safety equipment.
Form 2112 R, Report and survey checklist of passenger ship safety equipment survey.
Form C11, Condition of load-line assignment.
Form 2115, Survey checklist safety radio.
Form 2116, Record of approval of radio installation.
Form 2137, GMDSS safety radio checklist.
Form 2138 Record of approval of GMDSS radio installation.
Survey report on last year's passenger ship safety survey.
Lifeboat/Tender certificates (if applicable).

Schedule and remarks list of last year's survey. (For example of this see Appendix "A".)

Blank copies of form 2112 R, form 2115, or 2137, annual survey checklist form, passenger ship safety certificate , form P, lifeboat/tender safety equipment certificate, if applicable, on form 1124 and interim certificate.

Confirmation from the vessels operators should be obtained that arrangements have been made for liferaft servicing, servicing of the fixed fire extinguishing system, portable and non portable extinguishers servicing, inspection of the radio or GMDSS installation.

It should be established from the records if the vessel has been examined in drydock within the last year of whether the operators have made arrangements to carry out an underwater examination.

All of the above excluding the dry-docking shall include confirmation that the firms or subcontractors involved are approved or acceptable to LR.

Time and date of the survey and location of the vessel during the survey should be clarified.

Availability of accommodation for the Surveyor(s) on board the vessel during the survey period should be confirmed.

Adequate and designated staff are to be available during the survey to assist the Surveyor(s).

The vessel and its equipment has been prepared for the survey.

3 The Survey

The scope of the Renewal Survey is as follows.

Verification that the Passenger Ship Safety Certificate, Record of Equipment for the Passenger Ship Safety Certificate (Form P), and any Addendum and Exemption Certificates are in order. That an examination of all the Surveyable items together with tests as considered necessary have been carried out to an extent, which in the Surveyor's judgement, shows a condition satisfactory until the next due survey, provided the required maintenance is being carried out.

The Owner's Representative should confirm that no unapproved modifications or additions to the Surveyable items on board have been made since the last survey.

Those items to be examined at a Renewal Survey are identified on the checklist (Form 2112 R.C.L.).

Renewal Surveys should be dealt with in their entirety. Only on those occasions where the required service facilities or necessary replacement equipment is not available locally may items be considered for deferment.

When the first visit is made and before any surveys are commenced, a meeting should be arranged where the Captain, Staff Captain, Chief Engineer, Safety Officer and Chief Electrician or their nominated deputies are present. A schedule should be drawn up giving approximate dates and times when each item can be examined and tested. (Appendix "A" gives an example of a schedule).

This schedule is maintained on a daily basis, incorporating any changes made for work already carried out. The schedule when updated at the end of the day can also contain the remarks or deficiencies list.

When arranging the schedule, the vessels cruise or service itinerary should be taken into consideration in order to avoid interference of the surveys with the passengers and cruise or cargo loading/discharge programs. This is ultimately the master's responsibility.

At the same time any changes to the vessel and equipment, made in the past year should be discussed, documented and later examined.

Any fires or other casualties which have taken place in the past year should be documented, examined and prepared for inclusion in the report.

The surveyor shall use this occasion to request copies of following:
Servicing records and certification of the vessels liferafts and hydrostatic release gear.

List of manufactures and or expire date of the vessels pyrotechnics.

Dates when the lifeboat or launchable liferaft call wires

were last renewed or reversed. Certificates for any renewals should be recorded.

Copy of the recent megger test of approximately twenty-percent of the vessels electrical equipment.

At the same time following documentation needs to be sighted and necessary details copied for the survey report: Stability manual, approval dates.

Damage stability and limiting KG curves, approval dates. For Ro-Ro passenger ferries the A/Amax degree of compliance shall be verified with the LR document on board.

Date of last lightweight or inclining experiment held.

Availability and approval date of the lifesavings, fire control and damage control plans.

Compass deviation card and RDF calibration curves.
Logbook entries for boat, fire drill, steering gear tests and abandon ship drills and other items as detailed in Section B.3 of the Report From 2112 RCL.

Instructions to master. It shall be confirmed that the vessel is operated in accordance with the approved loading conditions. The "Guidance Notes to the Master" should be verified on board.

The survey must be carried out using the following plans (or equivalent booklets) as a reference:
Fire Control Plan
Damage Control Plan
Lifesaving Plan

4 Report of Passenger Ship Safety Survey Form 2112 R (Report)

Page 1, the relevant entries shall be made as applicable.

Page 2, shall be completed in full giving, details of repairs and renewals now carried out.

Alterations and renewals, which affect the Passenger Ship Safety Certificate, all information affecting the record of Passenger Ship Safety Equipment form 2114 should be reported, indicating that copies of the relevant amended pages are forwarded to London Office.

5 Survey Checklist Form 2112 RCL (Checklist)

For ease of use, the items below are numbered as per the form 2112 RCL (Checklist)

5.1 A. General

A.1 Changes made affecting the validity of the Passenger Ship Safety Certificate shall be reported on page 2, of the report of the PASS, form 2112R in the general report section.

As the maximum validity period of the PSSC is one year, this item applies only to conditions caused by alterations or renewals requiring a limited validity of the PSSC.

A.2 Instructions and notices including muster lists and training manuals are to be examined for correctness, language and confirm that they are posted in the correct location. See SOLAS Chapter II-2, Regulation 8.

A.3 Class and other statutory certificates must be valid and in order at the time of PASS completion.

The expiry and endorsement dates are to be recorded. See proforma and certificates on board.

A.4 CSH and CSM items confirmed up to date, see proforma.

A.5 Boiler and pressure vessel survey confirmed up to date, see proforma.

A.6 Master, officers and crew certification as required by training standards and watch-keeping convention, (STCW) are to be confirmed.

A.7 Minimum compliment confirmed in compliance with the safe manning document.

A.8 Fires necessitating the operation of the fixed or portable system since the last PASS, report details on page 2. In case of a previous fire, it shall be confirmed that this was reported and necessary action taken. When this is not the case, the location of the fire should be examined, recommendations made, used equipment examined and recharged, details to be reported.

5.2 B. Documentation

B.1 The numbers, location and availability of approved drawings and documentation are to be checked and reported upon.

Fire control, lifesaving and damage control plans or booklets, should have an approval stamp indicating acceptance by the flag state or their representative. All modifications and updates shall be listed on the plans and shall reflect the latest SOLAS requirements.

In some cases these plans do not reflect the actual location of equipment on board. This must be corrected during the survey and London office (CSD/SAS/PASS) advised.

Trim and stability booklets, damage stability and loading conditions shall be approved, by or on behalf of the Flag State.

For passenger ferries and passenger Ro-Ro vessels, the degree of compliance with the A/Amax requirements shall be verified. This requirement is on a sliding scale dependent upon compliance.

The nautical publications are, up-to-date charts, sailing directions, list of lights, Notice to Mariners, latest edition, tide tables, current nautical almanac.

B.2 The inspection of the radio station or GMDSS installation must be carried out by a recognised radio inspector, verified by the surveyor and reported on forms 2115, or form 2137, after 1999 on form 2137 only.

B.3 Log book entries. These should be verified during the initial schedule meeting on board, extracts from the logbook may need to be translated, in many instances, logbook entries are not made or are incomplete. The Surveyor should personally examine the log book and satisfy himself as to the completeness of the entries made.

The date of the last full muster of passengers and crew for boat and fire drill is the date prior to this survey and should be recorded on the checklist.

Confirm that at that occasion the equipment of the lifeboats was examined and found in order.

The records of the onboard training of the crew members, in safety matters, should be verified.

Verify that the persons in charge of survival craft and their second in command, have a list of survival craft crew, confirm the listed persons as being on the present crew list.

B.4 Check that master is aware of SOLAS II-2 Reg. 21 availability of fire extinguishers.

B.5 SOLAS requires watertight doors to be closed at sea, and entries to this effect should be made in the ships logbook. Some vessels have a partial exemption from this requirement by the Flag State. Appendix "B" gives an example of a standard questionnaire for the vessels master and his staff to confirm items B.2, B.3, B.4 and B.5.

5.3 C. Watertight Integrity

C.1 This item can be satisfied with a docking survey or underwater examination. SOLAS requires "the outside of the vessels bottom" to be examined annually. Some flag states agree on a two-year docking survey and an underwater examination in the alternate year.

The under water examination should be held by experienced divers, preferably with CCTV and in water with a good visibility. The Surveyor should be in attendance.

The examination should include bottom shell, bow, stern and underwater side shell plating, bilge keels, stern frame, rudder, sea chests and strainers, stabiliser box and shell openings, bow and stern thruster units.

C.2 Propeller to be visually examined by the divers. Shaft seals to be reported on as tight, when found to be so.

C.3 Rudder bearing clearance to be taken where possible otherwise to be reported on page 2 of the report 2112R as rudder bearing clearances not taken.

C.4 Propeller shaft clearances to be taken where possible, otherwise to be reported on page 2 of the report 2112R as propeller shaft clearances not taken

Items C.2, C.3 and C.4 can be further reported on, when the vessel is in dry-dock. Clearances when available shall be reported in the form 2112R page 2.

5.4 D. Ballast Stowage

D.1 Solid ballast stowed as per plan. The permanent solid ballast should be examined in the stowed location and the Surveyor is to satisfy himself that the solid ballast remains adequately secured, and has not deteriorated or has become excessively corroded. It is important that the location and quantity of solid ballast is carefully examined, after temporary removal of the ballast for survey or repairs.

D.2 Permanent liquid ballast, to be confirmed as per approved stability booklet and loading conditions. Soundings to be taken to confirm the quantity.

D.3 Ballast arrangement, to be verified to confirm compliance with the approved loading conditions.

5.5 E. Watertight Bulkheads

E.1 Integrity of all subdivision, watertight bulkheads to be verified. The Surveyor should examine all watertight bulkheads, specially in areas just above tank-tops and decks, where water can accumulate, also in way of watertight doors, at the ships sides and in way of pipe and cable penetrations. Special attention should be given to areas where recent alterations, conversions or repairs have taken place. Existing bulkhead penetrations for cables or pipes should be carefully examined for condition. Figure III.1.

Any additional bulkhead penetrations to be verified in accordance with Convention requirements.

E.2 Remote controls for bulkhead isolation valves on the bilge, black and grey water systems should be operated and open/closed indication verified. Pneumatically or hydraulically operated valves should be examined during the opening and closing operation, to verify that the actuator disk is secure on the shaft. The open/closed remote indication on automatic systems, fails frequently due to wrongly adjusted limit switches.

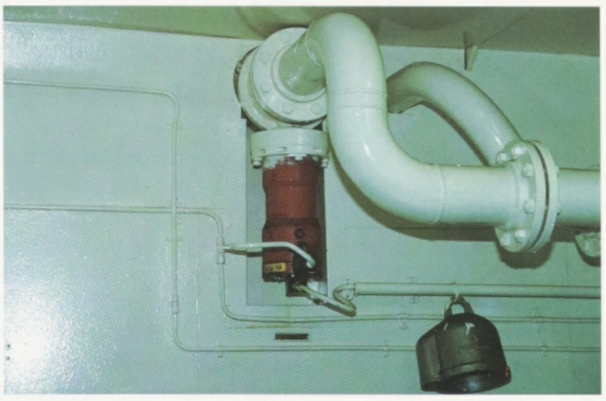


Figure III.1
Watertight bulkhead valve

It is also important that the piping of these systems is examined for wastage and temporary repairs.

In older vessels where the bulkhead isolation valves are remotely controlled with hand-wheels or keys and extended spindles, the spindles and universal joints shall be carefully examined and operation tested. Portable keys should be located close to the operation point and be clearly marked.

Access to the positions where the remote location is situated shall be verified and markings of the valve controls checked.

5.6 F. Watertight Doors

F.1 Watertight doors should be closed from the bridge, proper closing should be verified at the door location. Older doors, when not properly maintained, may not close completely, which will be a reason for leakage in case of an emergency. Doors of the gasketed type need to be examined for wear and damage of the gaskets. All water tight doors should be capable of being closed from both sides of the bulkhead. This to be tested.

It should be verified that notices and operating instructions of the system, are posted on the bridge and for local operation at both sides of the doors, in a language understood by the crew.

When operating the doors remotely an alarm bell should be activated at the door location.

Watertight doors which are hydraulically operated, should be fitted with an accumulator system, which will operate the door in the sequence closed-open-closed. This should be tested, in older vessels the accumulator systems tend to loose their charge or suffer from valve and coupling leakage.

Doors, which are electrically operated, with an electric motor on each door, are not required to be fitted with an accumulator system.

When a watertight door has been closed from a central control station and this is kept activated, it shall automatically close, when opened locally. This should be tested.

Power operated watertight sliding doors are to be provided with manual gear on either side of the bulkhead to close and open the door. The manual gear can be either mechanical or hand hydraulic. This should be tested.

F.2 It should be verified that the control handles of the local operating system are in such a position that they can be held open simultaneously, to allow safe passage of personnel in case of an emergency.

F.3 Indicators on the bridge and at other remote operation positions should be verified. Audible and when fitted visible alarms for these modes to be verified at the doors.

F.4 Doors are to be closed by hand from above the bulkhead deck.

F.5 Door operation by hand, locally at the door to be verified. Note that during any manual operation of the doors, the power pumps should be switched off, to avoid pressure build up in the system, resulting in a dangerous situation.

F.6 Lay-out diagram of the door location on the bridge, with door position indications, to be verified.

F.7 Operating notices and warnings of non-remote operated doors to be verified. It should also be checked that of these doors the self closers, latches and cleats are in satisfactory condition.

5.7 G. Portable Plates

G.1 Portable plates, manhole covers, should be checked for condition and verified that they are closed, this applies to all tanks, cofferdams and void spaces. Portable plates shall be in place before the voyage commences and kept closed whilst the vessel is at sea.

G.2 Notices and labels on the portable plates shall be verified in place and be appropriate to the space protected.

5.8 H. Shell Openings

H.1 Shell side doors should be operated, examined and verified tight. Cleats, strong backs, rubber gaskets, impression and retainer bars, shall be examined. When fitted, indicator lights on doors and closing arrangements, installed locally or on the bridge should be tested.

H.2 Non opening, key operable sidelights and windows should be examined, the arrangements for control of the key for closing the sidelights determined and agreed upon. Sidelights and windows to be checked for broken or cracked glass.

H.3 Dead-lights and window covers to be verified. They should be readily available for immediate use. The form C11 should be consulted to determine where dead-lights and shutters are required.

H.4 Galley chute, where fitted, to be checked for weathertightness. The present pollution requirements and garbage disposal regulation prohibits almost all dumping at sea. This has resulted in the removal of this equipment from most vessels.

H.5 Scuppers sanitary and other discharges, shell valves and their remote controls. All of these should be examined for leakage, wastage and accessibility.

Remote operating equipment to be tested.

It is noted that many of these valves and discharges are located behind linings therefore it should be verified that access doors are properly labelled and not obstructed. The Report C11 should be consulted for location and quantity.

H.6 All bridge indicators for shell openings, when fitted, should be verified and tested.

H.7 Means of detecting leakage water through shell openings, bow visor, bow door space in the case of RO-RO vessels, to be tested

H.8 Sea inlet and discharge valves to be generally examined for wastage, leakage, accessibility and status indicator to be verified.

H.9 Drainage of the special category spaces is to be verified as being efficient by a full scale test of the drencher system.

H.10 Sewage tank arrangement, venting and overboard discharge to verify. Most modern vessels have only one overboard discharge per system.

5.9 I. Watertight Integrity above the Margin Line

I.1 Water tight integrity above the margin line, partial water tight bulkheads on the bulkhead deck, to be examined for watertight integrity. Pipe and cable penetrations, and splash tight doors to be examined and verified in order. Splash tight doors have the same operating facilities as fire screen doors and watertight doors.

I.2 Weather tight closures of all openings on the weather decks. Basically all of this equipment can be found in the C11 report. All hatches, weathertight doors, hatch covers and hatch coamings should be examined, together with their closing appliances.

Air-pipes should be examined and depending on the type opened up for examination of the closing appliances, e.g. ball floats.

It is noted that on passenger vessels most air-pipes closing appliances are fitted on the freeboard deck, behind the linings, venting directly overboard.

Access shall be made to examine all of these.

All exterior ventilators and their closing appliances should be examined and closing appliances operated.

Note that in many cases the closing appliance is also the fire damper.

I.3 Freeing ports, bulwarks and guard rails, should all be examined for condition and where freeing port covers are fitted they should be operated.

5.10 J. Bilge Pumping

J.1 Bilge pumps, main and emergency should be operated and tested, by pumping the local bilge wells into a bilge tank.

A minimum of three bilge pumps are required. The pumps and bilge main are fitted inboard of the B/5 line. The pumps should be fitted such that in all flooding conditions at least one pump remains available for use. One of the bilge pumps fitted outside the main generator rooms, should be powered by the emergency generator.

The distribution boxes valves and bilge lines should be arranged such that in case of flooding one of the bilge pumps remains operative on any compartment in the vessel.

If there is only one system with common pipes to all pumps than the necessary valves in the system should be remotely controlled from above the bulkhead deck.

In the case of an emergency bilge system fitted in addition to the main system, capable of operating in all compartments, then only the valves necessary to operate this system should be remotely controlled from above the bulkhead deck.

All remotely controlled valves, must have their controls clearly labelled, and provided with means to indicate whether they are open or closed at the remote control station.

J.2 Remote starting of all the bilge pumps should be tested.

In modern ships bilge-valve and pump controls are located in a damage control station. All pumps and valves should be operated from the control station and operation verified locally.

J.3 Remote controls of all valves should be tested. See J.2.

In case of a vessel fitted with hand wheel and extended spindle remote control, spindles, universal couplings open/closed indicators should also be examined.

5.11 K. Sounding Pipes

K.1 Lever weighted cocks in machinery spaces should be operated. When lifted, the weight should automatically drop and close off the sounding pipe. It should be checked that all sounding pipes of this type are fitted with caps, attached with a chain to the pipe. Labelling as to which tank they serve to be verified.

K.2 Flush deck type accommodation sounding caps, to be examined and verified accessible, labelled as to which tank they serve, locations indicated on the damage control plan and caps easily removable.

K.3 Remote sounding devices for tanks and spaces, to be checked for accuracy and verified giving correct level indications.

5.12 L. Cross Levelling and Dumping Arrangements

L.1 Swimming pool draining time to be checked. The time between opening the drain valve of the swimming pool and being empty should be in the order of 15 minutes. Valves verified properly labelled.

L.2 Cross flooding arrangements should be verified, valves and flaps should be tested, including their remote controls, when fitted.

Tank systems fitted with cross flooding connections are fitted with a valve system which should be remotely operable, both valve and remote operation to be tested.
In older vessels these, sometimes large, valves become inoperable due to deposits.

Machinery spaces with a centre line bulkhead, may have cross flooding flaps fitted in the bulkheads under the floor plate (refer to damage control plan).

L.3 Blow out plugs and flaps to be verified. These arrangements are mainly fitted in older vessels in storeroom and refrigerated spaces below the bulkhead deck. They should be checked for access, labelling, clear of obstructions and verified as being operable.

L.4 Down flooding arrangements verified. These arrangements are often vertical closed trunking systems, some of them fitted with spring-loaded or collapsible covers, which are to be tested for satisfactory operation. Down flooding arrangements are indicated on the damage control plan. They can be found in most vessels fitted at the ships side. To satisfy the damage control requirements, modern vessels have down flooding trunks fitted about the margin line, at the ship side, in way of the watertight bulkheads, most of these are of the closed trunk type.

L.5 Stabiliser dump system to be verified, this can mainly be found on older vessels having a stabiliser or flume tank system. It should be tested for satisfactory operation.

5.13 M. Load-line and Draught Marks

M.1 Load line marks to be verified, freeboard to be checked as being in accordance with the loadline certificate. Loadline marks to be repainted if necessary. Figure III.2.

M.2 Draught marks or reliable draught indicating system to be checked. Draught marks to be repainted if necessary.

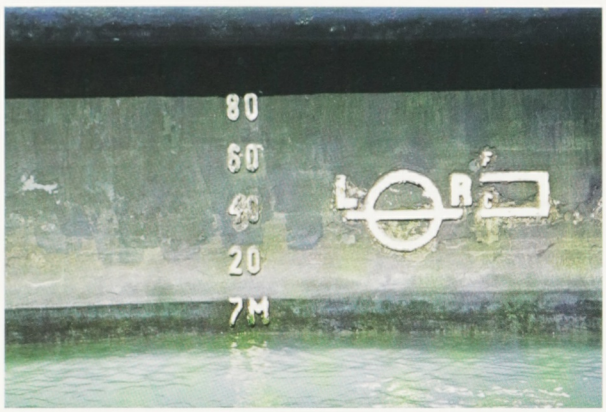


Figure III.2
Maintenance required on marks

5.14 N. Stability and Operating Practice

N.1 Approved stability manual and loading conditions to be verified on board, approval dates to be recorded. Is important to verify that the latest edition bearing the approval stamps from LR or flag state administration is on board.

N.2 Master's statement is to be obtained, confirming that the vessel is being operated in accordance with the Master's stability instructions.

5.15 O. Machinery and Steering Gear

O.1 The boilers, other pressure vessels and their appurtenances, including safety devices, foundations, controls, relieving gear, high pressure and waste steam piping, insulation and gauges, are to be generally examined. The Surveyor should confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

It should also be verified that the dangers due to moving parts, hot surfaces and other hazards are minimised.

It should be confirmed that the relevant machinery surveys for classification purposes are up to date, conditions of class machinery have to be reviewed and the Surveyor has to satisfy himself that no conditions of class are overdue or cause an unsatisfactory condition for the vessel's passenger ship safety equipment.

O.2 The normal operation of the propulsion machinery being sustained or restored in the event of one essential auxiliary becoming inoperative, to be verified.

Special attention should be given to the following:

1. Other generator sets.
2. Sources of steam supply.
3. The boiler feed water system, mechanical air supply.
4. Fuel oil supply for boilers and engines.
5. Sources of lub. Oil and water pressure.
6. Condensate pump, is vacuum maintained in condensers.
7. Air compressor and air receiver for starting or control purposes.
8. Hydraulic, pneumatic or electric means for controlling the main propulsion and propulsion systems

O.3 Verify the means to bring the machinery in operation from dead ship condition without external aid.

The first start arrangement has to be tested. This should include the testing of the means of starting the emergency generator. When one of the starting modes is air-start, the diesel driven air compressor should be tested, the emergency air receiver should be generally examined, the tightness of the valve between emergency and main air receiver, should be checked for tightness.

O.4 Means to protect against over pressure of main auxiliary and other machinery to be verified, safety valves, etc. and their settings. See also O.1.

O.5 Crankcase explosion relief devices to be verified. Verify that the surveys of the relevant machinery items have been carried out.

Internal combustion engines with a cylinder diameter of 200 mm or more, or a crankcase volume of .6 m3 and above, should be provided with crankcase explosion relief devices. The relief devices should be arranged, or provided with means to ensure that discharge from them is so directed as to minimise the possibility of injury to personnel.

O.6 Verify the maintenance of the automatic shutoff arrangements fitted to main and auxiliary machinery.

Check the engine room log and the maintenance records on board the vessel.

O.7 Means of reversing thrust of propeller(s) to verify. CP installation, direct reversing or gear box reversing of the propeller thrust. The Surveyor should verify this during the manoeuvring operations of the ship.

O.8 Maintenance of the main and auxiliary steering gear to be verified. Carry out a general examination, operational test to be held. Check status of ES or CSM regarding steering gear items. Check the engine room log and the maintenance records on board the vessel.

O.9 Verify that failure of either main or auxiliary steering gear does not render the other inoperative.

With main and auxiliary steering gear in operation, verify that, when one of the modes is switched off, the other maintains steering effective capabilities.

Items O.9 through O. 30 shall be verified during the steering gear operational tests.

O.10 Verify that auxiliary steering gear can be speedily brought in action in case of an emergency. To be verified by witnessing a test of this.

O.11 Verify that the lubrication arrangements for the essential components of the steering gear are in good condition.

O.12 Verify that the relief valves in the steering gear hydraulic system are set to the correct pressure. Relief valves shall be fitted to any part of the steering gear that can be isolated and in which pressure can be generated from the power source or external force.

O.13 Verify the automatic restart of the main and auxiliary steering gear power units after a power failure.

O.14 Confirm the capability of the main and auxiliary steering gear being started from the bridge.

O.15 Verify audible and visible alarms on bridge, indicating a power failure of any one of the steering gear power units.

O.16 Verify and test the control system from bridge and main steering gear room to main steering gear.

O.17 Where auxiliary steering gear is not fitted, verify and test the two independent control systems from the bridge for the main steering gear power units.

O.18 Verify and test the operation of the control for the auxiliary steering gear in the steering gear compartment and if power operated also from the bridge.

O.19 Verify and test the bridge control for the auxiliary steering gear. This system shall be independent from the control system for the main steering gear.

O.20 Verify and test the audible and visible alarm on the bridge indicating the failure of electrical power to the steering control system.

O.21 Verify and test the communication between bridge and steering gear compartment. Two independent modes shall be available.

O.22 If provided with an emergency steering position verify the communication to relay heading information and visual compass readings.

O.23 Verify and test the independent rudder angle indicator on the bridge. Compare bridge indicator with angle of steering gear and rudder.

O.24 Verify rudder angle indicator in steering gear room.

O.25 Verify the working of the audible and visible low level alarms for the hydraulic steering gear. Alarms shall be fitted on the bridge and in the machinery space.

O.26 Verify the means to recharge one hydraulic actuation system from a storage tank in steering gear compartment. The storage tank should have a capacity to recharge at least one power actuating system including the reservoir. The storage tank shall be permanently connected by piping, not hoses, in such a manner that the hydraulic system can be rapidly recharged from a position within the steering gear compartment and should be provided with a content gauge.

O.27 Verify the ready accessibility of the steering gear compartment. A steering gear compartment should not be used as a storeroom.

O.28 Verify the arrangements to ensure the safe working access to the steering gear machinery and controls. This should include handrails and gratings.

O.29 Verify the indication on the bridge and in the engine control room, that the motors are running in case of an electric or electro hydraulic steering gear.

O.30 Verify the overload alarm and loss of phase alarm for the three-phase supply in the engine control room. Where a three-phase supply is used, an alarm should be provided that will indicate a failure of any one of the supply phases. These alarms should be audible and visible and situated in the machinery space control room.

O.31 Check the chief engineer's records on the maintenance of means of control, main and auxiliary machinery for propulsion and safety of the ship.

O.32 If fitted verify the means for remotely controlling the propulsion machinery from the bridge. This can be carried out during the survey when vessel departs or enters a port. When the propulsion machinery is remotely controlled from the bridge and the machinery space is intended to be manned, then the following applies:

The speed, direction of the thrust and the pitch of the propeller should be fully controllable from the bridge. The main propulsion machinery should be provided with an emergency-stopping device. The remote control should be arranged for each independent propeller. Propulsion machinery orders from the bridge should be indicated in the main machinery control room. Remote control should be possible only from one location at a time, at such locations interconnected control positions are permitted. At each location there should be an indicator showing which location is in control. Transfer of control should be possible only in the main machinery space, for changing from bridge to engine room control or reverse. Local control should be possible on the propulsion machinery.

O.33 Verify the arrangements to operate main and other machinery from the machinery control room. This can be carried out during the survey when vessel departs or enters a port.

O.34 Verify the maintenance of means for manually overriding automatic controls and check that their failure does not prevent the use of the manual override. Check the chief

engineer's records on the maintenance of these means of controls.

O.35 Verify the safety features fitted on oil fired, exhaust gas boilers, unfired steam generators, steam pipe systems, air pipe systems and air pressure systems. This is to be carried out during the general examination of the vessels boilers. See O.1. This includes low boiler water alarm and burner cut out, pressure relief devices and pressure gauges on compressed air lines, steam pipes.

O.36 Confirm the satisfactory operation of the machinery space ventilation system. To be carried out when the machinery space ventilation remote stops are tested.

O.37 Verify the noise prevention in the machinery space. Verify that ear defenders are provided and that the necessary sound insulation as originally fitted is in satisfactory condition.

O.38 Confirm satisfactory operation of the engine room telegraphs by giving visual indication of orders and answers in the machinery space and on the bridge.

O.39 Verify the second means of communication between navigation bridge and machinery space located at all positions from which the engines may be controlled.

O.40 Verify the audibility of the engineer's alarm in the engineer's accommodation spaces.

O.41 Verify the precautions taken to prevent oil escaping under pressure, coming into contact with heated surfaces. Check oil systems for tightness, fuel lines where required are of the double wall construction, drip trays are to be fitted where necessary, with drains un-blocked, heated surfaces adequately insulated and exhaust manifolds and pipes insulated.

O.42 Verify the precautions taken to prevent over pressure in oil tanks and oil systems. Fuel tanks to be confirmed fitted with quick closing valves.

5.16 P. Electrical Installation

P.1 Twenty percent of the electrical installation should be megger tested, verify that this represents equipment not done in the last four years, but ensure that it includes essential services for the propulsion, steering and safety of the vessel and services necessary for minimum comfortable conditions of habitability.

Reference should be made to the records held on board to verify that the complete electrical installation is tested over a five year period.

P.2 The emergency generator to test load and starting methods to be verified as follows:

Locate circuit breaker on main switchboard supplying the emergency switchboard. If two inter-connectors (tie) breakers are located on the main switchboard, arrange the second breaker in the disabled position. With the emergency generator set for automatic mode, trip tie breaker on the main switchboard. Incoming tie circuit breaker on the emergency switchboard will also open to prevent feed back operation. Emergency generator will start and generator circuit breaker will close to the emergency switchboard automatically.

P.3 Emergency battery capacity, for transitional source of power, to be verified by a battery essential discharge test. The battery bank(s) should be disconnected from the charger, the services connected and run for half an hour. The voltage should remain within 12 % of its nominal voltage during that period.

P.4 Verify that all earth detection devices have been satisfactorily tested and all low resistance measurements traced and rectified Minimum requirement 0.1 M Ohm.

P.5 Verify the arrangement for unattended machinery spaces, UMS requirements

P.6 Supplementary emergency lighting, disposition to be verified and installation satisfactorily tested.

5.17 Q. Pumps, Fire-main, Hydrants, Hoses, Etc.

Q.1 All fire pumps, to be tested one by one, each with two hoses connected, producing simultaneously a jet of water of 12.5 metre each in any location on board the vessel. The test locations should, for this reason, be at the highest hydrant positions.

The fire pump location should be such, that a fire in any one compartment will not put all fire pumps out of action. One of these fire pumps, when electrically driven needs to be arranged for power supply from the emergency switchboard. The automatic and remote start up of this pump should be verified.

Q.2 All fire pumps should be tested individually, at the pump location, for checking condition, proper operation and verifying pressures. Fire main to be pressurised and checked for leakage and wastage. Isolation valves to be operated, access to these valves to be kept clear. Relief valve setting to be verified.

The fire main is to be continuously pressurised, so that at least one jet water is immediately available from any internal hydrant. Pressure drop shall activate one of the main fire pumps, in order to restore the required pressure. The proper working of this should be verified.

All hydrants to be checked for condition, leakage, condition of hydrant hose connection gaskets, ease of opening and closing. Figure III.3.

All hoses to be examined, when any doubts about the condition, the hoses can be coupled, pressurised and checked for leakage, hose connection to coupling to be specially examined for condition. Worm drive clips are not acceptable.

All hose nozzles to be examined for condition and for correct type.



Figure III.3
Fire hydrant, hose and nozzle

Fire hose boxes and reels are to be examined for condition and availability of spanners (suitable for the coupling as fitted).

International shore connections to be examined, number as per fire safety plan. The international shore connections should be capable of being used from both port and starboard sides.

Q.3 Verify that the fire hoses, complete with couplings, nozzles and tools are properly fitted in the hose boxes, on reels when applicable and connected to the hydrants where required. In interior locations in passenger ships carrying more than 36 passengers fire hoses should be connected to the hydrants at all times. In the machinery spaces all fire hose should be connected to the hydrants at all times.

At least one hose should be provided for each hydrant in accommodation spaces.

The fire fighting capability from the hoses and hydrants is to be achieved with all watertight doors and fire doors in main vertical zones closed.

When hose ports are provided in fire screen doors, they should be checked for proper operation and self-closing after use.

Q.4 Long handled water fog applicators. Machinery spaces of category "A" in passenger ships carrying more than 36 passengers. Each machinery space of category "A" should be provided with at least two suitable water fog applicators.

In passenger ships carrying more than 36 passengers, for each pair of breathing apparatus there should be provided one water fog applicator which should be stored adjacent to such apparatus.

5.18 R. Portable Extinguishers

R.1 It should be verified that all portable fire extinguishers are fully charged, in satisfactory condition and stowed in a bracket in the appropriate position. Type, number and locations as per approved fire control plan.

Where a specialist firm of fire engineers is used to carry out maintenance of the extinguishers, Surveyors should ensure they are a recognised firm competent to carry out the work.

Surveyors should check the number, distribution and condition of all fire-extinguishers and portable foam applicators. In the case of portable foam applicators the supply of foam concentrate is to be replaced at intervals not exceeding 10 years. In the case of an extinguisher of 45 litres capacity and over, Surveyors should check the foam forming qualities of the solutions and examine the operating mechanism and hose. The charge should be withdrawn at least once in four years and the internal condition of the extinguisher verified:

1. The solution is to be replaced at intervals not exceeding 10 years.
2. If the Surveyor considers it advisable, the extinguisher should be subjected to a hydraulic test of 21 bar or, in the case of extinguishers fitted with a bursting disc or other relief device, to not less than the intended relief pressure.

All portable fire extinguishers, other than CO_2 extinguishers, should be tested by hydraulic pressure to 21 bar about once in four years, and the date of the test marked on the extinguisher

A proportion of foam and water type extinguishers should be discharged during the survey.

Portable CO_2 extinguishers need only be emptied if the weight of gas is less than 90 per cent of the stated capacity. If, when the cylinders are emptied, four years have elapsed since the date of the last hydraulic test (as shown by the test stamp on the cylinder), the cylinders should be tested to the bursting pressure of the safety disc before being recharged.

The Surveyor should be satisfied that the extinguishers have been properly tested if he has not witnessed the tests. The firm's written assurance that the extinguishers have, subsequent to the pressure test, been correctly serviced and recharged, may be accepted.

Surveyors should check that the operating instructions are displayed on the sides of the extinguishers in a language or languages understood by the crew.

R.2 Date when the portable fire extinguishers were charged, to be completed. When in case of passenger ships, the crew has serviced and recharged the portable extinguishers, a statement to this effect should be obtained from

the master. The extinguishers should be examined by the Surveyor and some, randomly, discharged. CO_2 extinguishers should always to be recharged by a specialist firm.

R.3 and R.4 Verify that at each boiler firing space a sand box with scoop, or an approved portable extinguisher is provided.

R.5 Spare charges for the portable extinguishers other than for gas cylinders. Considering the large number of portable fire extinguishers on board passenger ships, it is recommended that an amount of approximately 10 % spare charges of each type, should be carried on board.

R.6 Spare gas cylinders. CO_2 extinguishers, as for the other extinguishers on board, approximately 10 percent spare, charged, CO_2 extinguishers should be carried.

R.7 It should be verified that on completion of the survey, all extinguishers are stowed in their position and a random check should be carried out to confirm that all extinguishers are fully charged.

R.8 Dates when cylinders pressure tested, in case of a variety of different dates, this information to be entered on page 2 of the PSSS report.

5.19 S. Non-Portable Extinguishers and Foam Applicators

S.1 Verify that all non-portable extinguishers and foam applicators unit containers are fully charged and stowed in position. Type, number and locations are as the approved fire control plan. Figure III.4.



Figure III.4
Non-portable (wheeled) foam fire extinguisher

A portable foam applicator unit should consist of an air-foam nozzle of an inductor type capable of being connected to the fire main by a fire hose, together with a portable tank containing at least 20 l of foam-making liquid and one spare tank. The nozzle should be capable of producing effective foam suitable for extinguishing an oil fire, at the rate of at least 1.5 m^3/min.

S.2 Report charging date for extinguishers and foam for applicators.

S.3 Report the date when the cylinders or containers were pressure tested, in case of a variety of different dates, this information to be entered on page 2 of the PSSS report.

5.20 T. Fixed Fire Extinguishing and Protection System

T.1, T.2, T.3, T.4, T.5, T.6 and T.7 For fixed fire extinguishing and protection systems the Surveyor should copy the required information from the report 2114.

T.8 Confirm that each system has as far as practicable been examined for condition of piping, nozzles, found clear of obstructions, gas release alarm system tested and clear operation instructions posted. Servicing details of any of the systems will be reported in the next paragraphs.

Servicing of all fixed systems on board passenger ships should be carried out annually.

5.21 U. and V. CO_2 and Halon Systems

U.1 and V.1 Halon and CO_2 systems, report the date when the gas container contents were verified.

U.2 and V.2 Halon and CO_2 systems, report the date when the containers were pressure tested.

U.3 and V.3 Halon and CO_2 system, report the date when the system was serviced.

U.4 and V.4 Halon and CO_2 systems confirm examination and tests as detailed below.

U.5 CO_2 only, means of closing of all openings of protected spaces and stopping of the boiler fans, ventilation fans, fuel pumps, etc. to be verified. In some cases the closing of ventilation dampers, stopping of fans, oil pumps, etc. in protected spaces, is automatically carried out when the fixed system is activated, this should be tested. Similar arrangements are fitted for Halon installations.

U.6 and V.5 Verify that clear operating instructions are posted at the storage locations and the operation panels, in a language understood by the crew.

5.22 W. Foam Systems

W.1 Fixed foam systems, report date when the foam sample was tested.

W.2 Systems to be examined as far as practicable.

5.23 X. Fire Doors in "A" and "B" Class Bulkheads

X.1 Held open type doors, bridge and locally operated to be tested from the bridge and locally.

Fire doors which in normal service remain open will usually be held in the open position by an electro magnet with a local release control usually, although not necessarily, from both sides of the bulkhead. These doors will also be capable of remote release from the navigating bridge/fire control station where a panel is located to indicate if the individual door is open or closed.

Fire doors will have been arranged by the manufacturer to close against a 3.5° adverse inclination, but usage, wear and tear will have weakened the doors springs and pushers, attention shall be paid to this and when found necessary re-adjusted.

Survey procedures are as follows:
By use of the 'test button', it should be ensured that all indicator lights, for open and closed position, are working on the mimic panel on the bridge/fire control station.

All doors are to be closed from the central control and confirmed at the mimic panel. In many cases the doors can be closed by main fire zone, which makes it easier to carry this test out when the vessels in operation.

Each door is to be operated individually using the local control switches and it is to be confirmed, that:
The damping arrangements are effective against excessive speed of closure, thereby avoiding injury to passengers;

Double leaf hinged doors close in the correct sequence;

The door latches in the closed position;

Where fitted, carpets terminate each side of the fire door and are not carried through;

Door release controls are properly marked;

The doors are numbered in accordance with the fire control plan;

No illegal hold back hooks or other arrangements have been fitted;

All doors are free from obstructions;

Doors on escape routes are not fitted with illegal locking arrangements.

Sliding doors fitted with an automatic retraction system, shall, be tested for that option.

X.2 Continuous use type doors, local operation to verify.

X.3 Permanently closed doors, local operation to verify.

X.4 All doors good condition and access free of obstructions to be confirmed.

5.24 Y. Ventilation

Y.1 Accommodation ventilator fan shut downs to be tested, this has in most cases to be carried out in port, it will also shut down any AC running and requires after the test resetting of ventilator fan starting system. Modern vessels have a central control panel for this purpose, located on the bridge, switches grouped by fire zone, allowing testing by fire zone. In older vessels the control switches are located in one of the upper deck's corridors.

Y.2 Machinery ventilator fan shut downs to be tested, this in most cases has to be carried out in port. In modern vessels a control panel is located on the bridge, with switches per fire zone, allowing testing per zone. This will limit the risks of shutting down engines. In steam ships this may create major operational problems and may have to be carried out in dry or wet dock.

Y.3 Special category space, ro-ro car decks etc., ventilator fan shut downs to be tested.

Y.4 Machinery space ventilation dampers, closing arrangements to be verified in satisfactory condition and operable. Figure III.5.

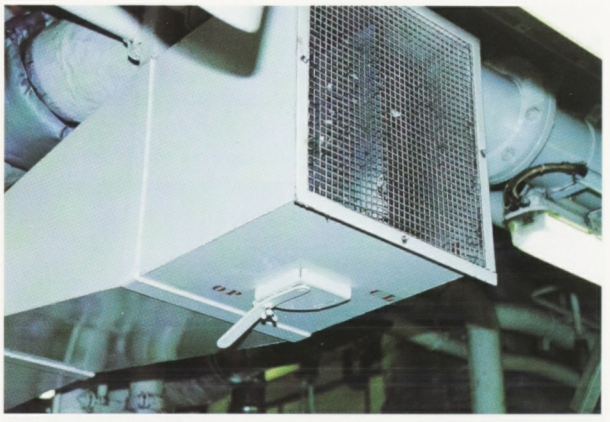


Figure III.5
Engine room ventilation intake damper

Y.5 Engine room sky light, when fitted, to be closed from the inside and outside of the engine room.

Y.6 Weather deck ventilation system dampers and their closing appliances to be tested. Both for inlet and outlet ventilators.

Y.7 Dampers in and on the outside of the fan rooms to be tested.

Y.8 AC and ventilation system dampers to be operated and tested, in case of dampers in ventilation trunks passing through main vertical zone bulkheads, from both side of the bulkheads. In many new passenger ships, fire dampers are pneumatically or electrically operated, controls for these dampers may be on either side of the bulkhead, but in

some case, one is at the bulkhead the other in a remote location, wheelhouse or ER control room. It is also required to check the operation of the damper actuator for proper working, damper shaft sometimes corrode and jam, or the actuator may turn around the shaft without moving the damper. The open and closed indicators are to be examined, for remote indication the corresponding position on the damper to be verified.

Y.9 AC and ventilation damper fusible links verified, all of those should be examined and checked, to verify that the damper shaft still moves freely.

Y.10 Galley ventilation cleaning system to be examined for proper operation and for cleanliness of the ventilation and exhaust system of the galley, access to the inspection opening to be verified, this includes the ones in the exhaust trunking above the galley and the vent casings.

Y.11 Fixed fire-extinguishing system in the galley exhaust system is to be examined and serviced.

Y.12 Labelling of the fire dampers and their controls to be verified.

Y.13 Shut downs for additional machinery space arrangements, boiler forced and induced draft fan are to be tested, this for operational and safety reasons may have to be carried out in dry or wet dock.

5.25 Z. Oil Fuel Tank Valve Quick Closing Gear and Fuel Pump Stops

Z.1 Oil fuel tank valve quick closing gear to be tested, all valves to be operated, in case of pneumatically controlled valve quick closing gear, the fail safe mode to be tested. The Surveyor should observe the testing of this equipment at the valve. The controls shall be located outside the machinery spaces or space where the tank is located. Figure III.6.



Figure III.6
Oil fuel tank quick closing gear

Z.2 Oil pump remote shut down to be tested, all of these pumps should be tested with the Surveyor verifying the shut down of the pump at the pump location. The controls should be located outside the machinery spaces. Figure III.7.



Figure III.7
Oil pump remote shut down controls

5.26 AA. Sprinkler System

AA.1 Automatic sprinkler systems. The sprinkler pump should be tested with the discharge open.

The automatic starting of the sprinkler pump should be tested as follows:

The sprinkler pump output should be arranged to discharge to the bilge by closing the valve which connects the pump to the sprinkler main and by opening the bilge discharge valve.

Check that the pressure switch which controls the pump is connected to the sprinkler main and bilge discharge by means of a 'T' junction, the legs of which have valves which can isolate the switch from the sprinkler main and the bilge discharge respectively.

To produce a pressure drop at the pressure switch, first close the valve on the sprinkler main side of the 'T' junction, then open the bilge discharge valve. The pressure in the pipe connection to the pressure switch shall fall immediately, causing the switch to operate and start the sprinkler pump.

On completion of the test the system should be reset to the 'standby' condition. This is done by closing the valve connecting the pressure switch to the bilge discharge, opening the valve connecting the pressure switch to the sprinkler main and finally opening the valve connecting the pump discharge to the sprinkler main and shutting off the bilge discharge valve.

Surveyors should verify that the pressure switch operates within the pressure limits set by the sprinkler system manufacturer.

The air compressor and the safety devices for the air compressor and the pressure tank should be checked.

The fresh water supply to the pressure tank should be checked.

The valve at the cross-connection to the fire main is to be operated satisfactorily, after which it shall be locked shut.

The operation of all electrical circuits and switching arrangements is to be checked.

AA.2 The pressure relief valve setting should be checked.

The sprinkler pump should be operated with the test valve discharge open to ensure that a pressure equal to the working pressure of the sprinkler, plus the pressure due to a head of water measured from the bottom of the tank to the highest sprinkler in the system, is maintained. A note should be made of the discharge pressure maintained during the test.

AA.3 Zone pressure and flow test valves to be operated and alarm indication on bridge verified. Figure III.8.

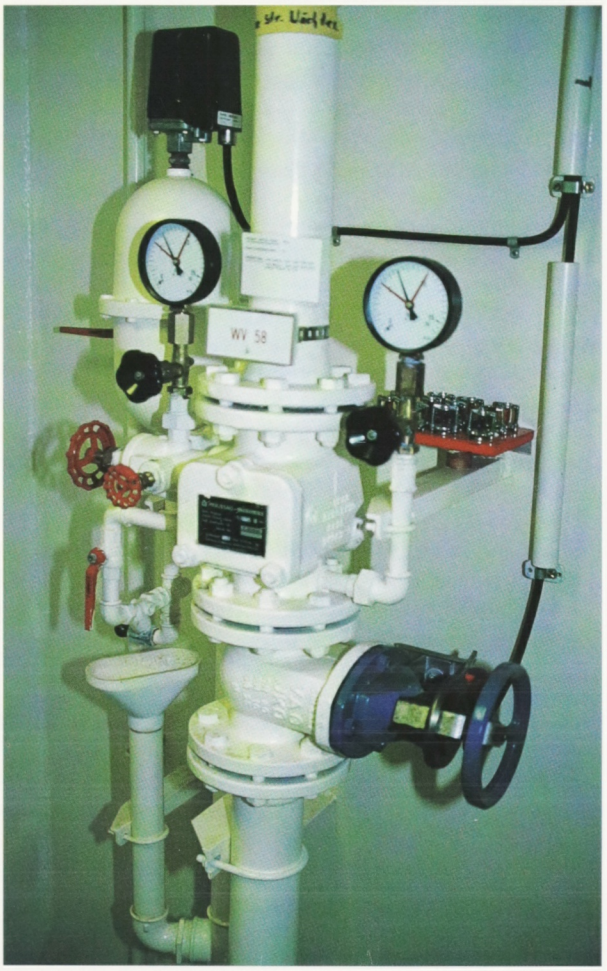


Figure III.8
Sprinkler pressure and flow indicating equipment

At each sprinkler station the test valve should be opened to verify that the appropriate alarm in the navigating bridge/fire-control room is operating. Additionally, the main section check valve should be throttled in order to check the alarm. The valve is to be fully locked open after verifying the alarm.

AA.4 Visual and audible alarm, with the system in operation to be verified. (see also AA.3) When checking the sprinkler stations the Surveyor or crew member accompanying him, should carry a two way-radio, a reliable person at the alarm panel with another two-way radio, will give the necessary confirmation of the working of the alarm.

AA.5 The condition of the pipe work is to be checked. Sprinkler heads should not be covered with paint, clogged with dirt, etc., or blanked off. The sprinkler heads should be located below the ceiling and not recessed, also the location shall be examined for any obstruction of the water spray.

AA.6 Spare heads availability to be checked. Six spare heads, of the type fitted in the section shall be available in the sprinkler station.

AA.7 Shore connection for the sprinkler system to be verified, this is in most ships a connection separate from inter national shore connection. It should be verified that the shore connection is fitted in the fire main. The cross over connection from fire main to sprinkler system should be verified in order with the cross over valve operable.

AA.8 It should be verified that a correct sprinkler zone lay-out plan is posted at the main alarm and control station on the bridge, further confirmation is required that a section plan indicating the spaces covered is posted at each sprinkler station. Instructions for testing and maintenance should be available.

5.27 BB. Fireman Outfits

BB.1 Fireman outfits, verify and confirm that each unit is in good condition and stored in the location as indicated on form 2114.

BB.2 Each outfit to be examined and confirmed complete.

BB.3 Verify the air compressor for recharging the air cylinders, when fitted, is operating properly. When fitted check the cascade system for recharging the air cylinders.

BB.4 When fitted, check and examine the smoke mask, air pump and hose.

BB.5 Long handled applicators to be verified stowed in each fireman outfit station.

5.28 CC. Fire Insulation

CC.1 Fire insulation is to be examined for the condition and satisfactory adhesion to the bulkheads, decks, vent trunks and cable penetrations.

Fire insulation may be in part shown on the fire control plans, but in most cases details are found on insulation plans, ventilation plans, plans of cable penetrations, plans detailing openings in "A' and " B" class bulkheads etc.

Included in the examination should be the complete fire insulation integrity of all "A" and "B" class division bulkheads, pipe penetrations and electrical cable penetrations, ventilation trunk penetrations, doors and windows.

5.29 DD. Draft stops, Smoke Holes, Etc.

DD.1 Draft stops which are fitted between deck-heads and ceilings, between side bulkheads and linings, should be examined for condition.

SOLAS Chapter II-2, Regulation 35, draft stops.

DD.2 Smoke holes when provided in ceilings and linings, should be verified for access and obstructions. Smoke holes are not required when other means are available to allow smoke from behind linings and ceilings. Gaps around sprinkler heads, smoke detectors, louvers in cabin doors, etc. The purpose of the smoke holes is to allow fire patrols and other staff to detect smoke originating from concealed and inaccessible spaces. Figure III.9.



Figure III.9
Fire hazard due to flammable material storage

DD.3 All machinery spaces, their bilges, etc., to be examined and confirmed clear of oil or other high fire risks materials. It should also be verified that flammable paints, solvents, oil containers are stowed in paint-lockers or other designated spaces.

Lockers, AC rooms etc., shall be examined and it shall be verified that materials and equipment of high fire risks are not stowed in such spaces, unless the locker has been designated for such materials.

5.30 EE. Means of Escape

EE.1 Means of escape to be examined, this should include all stairways, ladders and passage ways, providing access to muster stations, lifeboat and liferaft embarkation stations, from passenger, crew and spaces where crew is normally employed.

The examination should include, access to ladders, stairways and corridors, illumination, including emergency lights and low location lighting, signs, directions and emergency exits.

EE.2 Means of escape from special category spaces to be confirmed, such as car deck spaces on board passenger ro-ro ferries etc.

EE.3 Means of escape from machinery spaces to be verified, special attention should be given to accessibility, emergency escape and illumination.

EE.4 All escape routes to be confirmed clear of rubbish.

5.31 FF. Drencher Systems

FF.1 Drencher system to be operated by zone.

FF.2 The connection to the fire main to be examined and confirmed in order.

FF.3 The remote starting of the drencher pump to be tested.

FF.4 Zone plans to be confirmed at all operating stations.

FF.5 General labelling of the control and system equipment to be verified in order.

FF.6 The drainage of the protected decks to be examined during the tests, blocked deck drainage system can cause flooding of the decks, giving a free surface effect, limiting the vessels stability to possible dangerous values.

5.32 GG. Electrical Detection System

GG.1 Electrical fire detection system, heads are to be operated.

GG.2 Audible alarm must sound automatically in crew accommodation spaces, service spaces, control stations, category "A" machinery spaces, if the bridge alarm has not been acknowledged within two minutes. This must be tested.

GG.3 System plan should be verified available on board.

GG.4 Verify that at least one spare detector is provided for every 10 detector heads or part thereof, of every specific type, with a minimum of one spare head for every type

The operation of the visual and audible fault signal should be checked, it shall be initiated by a power supply failure or fault condition in the electrical circuits.

Initially the activation of 10 per cent of detector heads shall be checked at random but at least one detector per loop shall be selected, by producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size or other phenomena associated with incipient fires to which the detector is designed to respond. An indication of the activated detector head is to be given, both visually and audibly, at the control panel and indicating units. The Surveyor may require to test more than 10 per cent of detector heads, should this be considered necessary. The total number of heads tested to be at his discretion and to his satisfaction.

Clear information is to be displayed on or adjacent to each control panel indicating the spaces covered and the location

of the system sections. Information shall be in the language or languages stipulated by the National Administration and be understood by the crew.

There should be not less than two sources of power supply for the electrical equipment used in the operation of the fire detection and fire alarm system, one of which should be an emergency source. The supply should be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system.

The control panel should be located on the navigating bridge or in the main fire control station.
Indicating units should, as a minimum, denote the section in which a detector or manually operated call point has operated. At least one unit should be so located that it is easily accessible to responsible members of the crew at all times, when at sea or in port, except when the ship is out of service. One indicating unit should be located on the navigating bridge if the control panel is located in the main fire control station.

A section of fire detectors which covers a control station, a service space or an accommodation space should not include a machinery space of category A.

Suitable instructions and component spares for testing and maintenance should be provided.

Smoke detectors need not be fitted in private bathrooms. Spaces having little or no fire risk such as voids, public toilets and similar spaces need not be fitted with an automatic sprinkler system, or fixed fire detection and alarm system. Galleys are to be fitted with heat detectors.

5.33 HH. Smoke Detection System (Extraction Type)

HH.1 Smoke detection, extraction system. Alarm indication of all protected spaces should be checked.

If the system serving the cargo spaces, is of the sample extraction smoke detection type which utilises either dedicated or CO_2 distribution piping, it should be checked by ensuring that smoke from the various compartments can be detected visually, or by the initiation of a visual and audible signal.

5.34 II. Break Glass Alarm System

II.1 Break Glass Fire Alarms. Individual alarms should be operated and verified that corresponding visual or audible signals are given on the bridge. At least 10 percent of the manually operated call points should be tested, with a minimum of one per loop.

II.2 The labelling of individual manual alarms should be checked. All call points should be numbered, corresponding to the alarm panel indicators.

5.35 JJ. Alarm and Public Address System

JJ.1 Alarms to summon the crew should be operated and separation from passenger accommodation should be verified.

A special alarm, operated from the navigating bridge or fire control station, should be fitted to summon the crew. This alarm may be part of the ship's general alarm system but it should be capable of being sounded independently of the alarm to the passenger spaces.

JJ.2 The public address system, throughout accommodation and service spaces and control stations should be verified. When testing this system, care should be taken that the test audio is transmitted via the PA system emergency station microphone situated on the bridge and not via the announcement system from the pursers office.

A public address system or other effective means of communication should be available throughout the accommodation and service spaces and control stations and open decks.

JJ.3 Fire patrol duration should be confirmed, route keys checked and the patrol records or computer records verified. Each member of the fire patrol should be provided with a two-way portable radio telephone apparatus.

For ships carrying more than 36 passengers an efficient patrol system should be maintained so that an outbreak of fire may be promptly detected. Each member of the fire patrol should be trained to be familiar with the arrangements of the ship as well as the location and operation of any equipment he may be called upon to use.

5.36 KK. Carriage of Dangerous Goods

KK.1 The carriage of dangerous goods arrangements are to be verified with the attachment to Report Form 211.

5.37 LL. Notices

LL.1 Emergency instructions should be displayed in all passenger cabins, this to be verified. Figure III.10.

LL.2 Verify that all signs indicating escape routes are properly displayed and adequately illuminated.

5.38 MM. Survival Craft, Rescue Boat, Associated Launching and Recovery Appliances

MM.1 Lifeboats, it is a good practise to lower all the lifeboats, port and starboard, into the water where they should be manoeuvred. In exceptional cases one side can be lowered to the water and the other side to the embarkation deck, but this shall not be encouraged. Surveyors should witness and not supervise these tests.

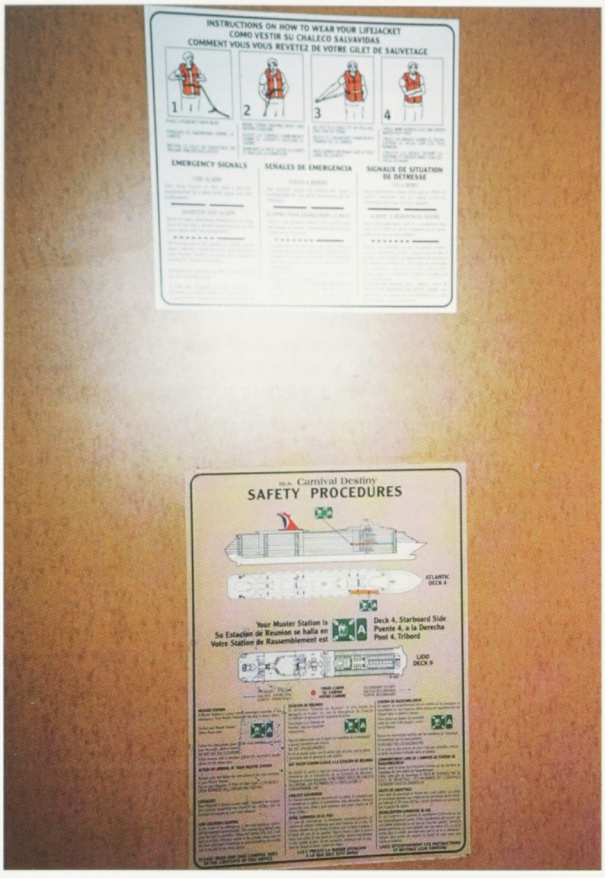


Figure III.10
Cabin notices

MM.2 When the lifeboats are lowered to the water all the launching gear should be used or tested, such as bowsing tackles, rudder, engine, reversing gear, lifeboat fall release gear, lifeboat davit winch brakes, etc.

MM.3 All engines and propulsion gear of the lifeboats have to be tested.

MM.4 The level of the diesel oil in the fuel tank to be checked and quantity verified sufficient for 24 hours continuous operation.

MM.5 Air-cases when fitted should be removed, tested for tightness, replaced and secured. Most modern lifeboats have built in buoyancy which should be examined for tightness. GRP lifeboats tend to sag after longer periods in the davits, this leads to crumpling and sometimes cracking of the upper structure, including the built in buoyancy. When such damage is found, the damage area should be cut out and renewed, using skilled GRP workers and reinforced as per manufacturers recommendations. In case of aluminium lifeboats, rivets tend to corrode at connection of the side wall and the lifeboat bottom plating.

MM.6 See MM.5

MM.7 Lifeboats should be examined for damage and wastage, passenger ships have mostly GRP lifeboats, but some of the older ones still have aluminium lifeboats, occasionally a steel lifeboat can still be found.

Lifeboats – General

Before commencing the survey of a lifeboat, Surveyors should ensure that the arrangements will allow the boat to be safely lifted clear of the stowage chocks.

It is essential that release mechanisms are fully engaged and locking pins or equivalent arrangements are in place.

Lifting hooks should be checked for wastage where they pass through the deck and in way of the keel attachment. The keel attachment should also be verified as being efficient.

Surveyors should sight the lifeboat certificates of approval, or check the boat details against the form 2114, to ensure that non-approved replacement boats have not been placed on board.

Lifeboat buoyancy arrangements:
Portable air cases, if fitted, should be removed, carefully examined and tested. Total immersion in water should reveal any deficiencies in the air cases. The structure in way of the air cases should be carefully examined and care taken to ensure that the cases are correctly re-fitted.

Material used to repair foam buoyancy should be an approved oil resistant type, which is also chemically compatible with the original material.

Loose foam blocks found in some older boats are susceptible to damage and water absorption and could be advantageously skimmed with G.R.P.

MM.8 Blocks, sheaves, wire falls, lifting hooks, hook foundations and securing arrangements, release arrangements and all moving parts to be examined and confirmed in good condition, free and well lubricated at the time of the survey.

MM.9 On load release gear and hydrostatic lock, should be carefully examined and the hydrostatic lock tested.

MM.10 Reversing or renewal dates of lifeboat falls to be reported.

MM.11 Lifeboat equipment to be examined

11.1	Number of persons the boat is certified to carry
11.2	Rowing oars/steering oar if applicable
11.3	Thole pin and crutch permanently attached or equivalent arrangement, one for each oar
11.4	Plugs with chain attached, one for each drain valve
11.5	Number of automatic drain valves fitted
11.6	Rudder attached with piller
11.7	Lifeline bucketed around outside of boat
11.8	Bilge pumps manually operated (1)
11.9	Lockers for small items of equipment
11.10	Painter (1) secured to stem, (1) secured forward with release device able to operate under tension
11.11	Boat hooks (2)
11.12	Food ration of approved type in airtight receptacles stowed in water-tight containers totally not less than 10,000kJ per person
11.13	Freshwater, 3 litres or 6 pints per person in water-tight receptacles or a desalting apparatus
11.14	Parachute signals, red (4)
11.15	Hand flares, red (6)
11.16	Buoyant smoke signals, orange (2)
11.17	Baler, buoyant (1)
11.18	Buckets with lanyard (2)
11.19	Hatchets with lanyard (2), one at each end of boat
11.20	Compass in binnacle, efficiently aluminised or illuminated
11.21	Sea anchor (1) with shock resistant hawser and a tripping line
11.22	Dipper, rust proof with lanyard (1)
11.23	Graduated drinking vessel, rust proof (1)
11.24	First aid outfit, approved type in water-tight case (1)
11.25	Electric torch, waterproof, suitable for morse code signalling (1), with spare set of batteries and spare bulb in waterproof container
11.26	Daylight signalling mirror (1)
11.27	Jack-knife attached to boat with lanyard (1)
11.28	Whistle or equivalent sound signal (1)
11.29	Fishing tackle (1 set)
11.30	Lifesaving signals on a waterproof card or in a waterproof container
11.31	Short ladder or other means of climbing into upright boat from the water
11.32	Skates or fenders (and skids if required) to facilitate launching against adverse list
11.33	Hand holds on underside of hull (only required on non self-righting lifeboats)
11.34	A survival manual
11.35	Six doses of anti-seasickness medicine per person
11.36	One seasickness bag per person
11.37	Tin openers (3)
11.38	Buoyant rescue quiot (2) attached to not less than 30m of buoyant line
11.39	Searchlight (1)
11.40	Efficient radar reflector (1)
11.41	Thermal protective aids (for 10% or 2 persons whichever is the greater)
11.42	Manually controlled internal and external lamps able to be operated for at least 12 hours
11.43	Sufficient tools for minor adjustments to the engine and its accessories
11.44	Water resistant instructions for starting and operating the engine are provided

MM.12 Additional requirements for partially enclosed lifeboats if vessel trades on restricted service (SOLAS 74/88 R III/42)

12.1	An effective means of bailing, OR
12.2	The lifeboats is fitted with automatic self-bailing arrangements
12.3	A permanently attached foldable rigid anti-exposure cover in way of open part of boat
12.4	Foldable cover is provided with means of collecting water

MM.13 Motor lifeboats (SOLAS 74/88 R III/41)

13.1	Starting system with two independent rechargeable energy sources
13.2	Fuel capacity sufficient for 24 hours running
13.3	Fire extinguisher, portable, suitable for oil fires
13.4	Propeller guard is provided
13.5	Exhaust pipe is provided with means to prevent ingress of water to engine
13.6	Engine transmission and accessories are enclosed in the fire retardant casing
13.7	Means are provided for recharging engine starting, radio and searchlight batteries

MM.14 Additional requirements for pre-SOLAS 1983 lifeboats (SOLAS 74 R III/11)

14.1	Bilge keels or rails
14.2	Grab lines gunwhale to gunwhale (2 minimum)
14.3	Light buoyant heaving lines (2)
14.4	Mast with galvanised wire stays and orange sail (not required for M or MP boats)
14.5	Cover, highly visible, for protecting occupants
14.6	Lamp with sufficient oil for 12 hours (1)
14.7	Matches in watertight containers (2)
14.8	Storm oil 4.5 lts (1 gallon)
14.9	Storm oil container, for attaching to sea anchor
14.10	Bowsing tackles to hold boat against ship's side

MM.15 All boats confirmed in compliance with SOLAS III Reg.41

MM.16 Verify the dimensions and number of persons, which has been permitted to carry, are permanently marked on the boat.

MM.17 Verify that the name and the port of registry of the ship to which the lifeboat belongs, are marked on each side of the bow.

MM.18 Confirm that it is possible to identify the ship to which the lifeboat belongs and the number of the lifeboat when viewed from above.

MM.19 Report which lifeboat pyrotechnics will expire in the period up to the next survey, indicate which lifeboat numbers.

MM.20 Report details, including boat numbers and expiry or manufacture dates, page 2 of the survey report, of any pyrotechnics now renewed.

MM.21 Confirm that all survival craft launching and recovery gear examined and found in satisfactory condition, examined as far as practicable.

MM.22 Confirm that each lifeboat is fitted with retro-reflective material, tape, and condition of this found satisfactory.

MM.23 Rescue boats
SOLAS III, Regulation 47 Rescue boats refers.

MM.29.1 – 29.2 – 29.3 Rescue Boat Equipment
.1 Sufficient buoyant oars or paddles to make headway in calm seas. Thole pins, crutches or equivalent arrangements should be provided for each oar. Thole pins or crutches should be attached to the boat by lanyards or chains;

MM.29.4
.2 A buoyant bailer;

MM.29.5
.3 A binnacle containing an efficient compass which is luminous or provided with suitable means of illumination;

MM.29.6
.4 A sea-anchor and tripping line with a hawser of adequate strength not less than 10 m in length;

MM.29.7
.5 A painter of sufficient length and strength, attached to the release device complying with the requirements of SOLAS Regulation 41.7.7 and placed at the forward end of the rescue boat;

MM.29.8
.6 One buoyant line, not less than 50 m in length, of sufficient strength to tow a liferaft as required by paragraph 1.6;

MM.29.9 – 29.10
.7 One waterproof electric torch suitable for Morse signalling, together with one spare set of batteries and one spare bulb in a waterproof container;

MM.29.11
.8 One whistle or equivalent sound signal;

MM.29.12
.9 A first-aid outfit in a waterproof case capable of being closed tightly after use;

MM.29.13
.10 Two buoyant rescue quoits, attached to not less than 30 m of buoyant line;

MM.29.14 – 29.15
.11 A searchlight capable of effectively illuminating a light-coloured object at night having a width of 18 m at a distance of 180 m for a total period of 6 h and of working for at least 3 h continuously;

MM.29.16
.12 An efficient radar reflector;

MM.29.17
.13 Thermal protective aids complying with the requirements of regulation 34 sufficient for 10% of the number of persons the rescue boat is permitted to accommodate or two, whichever is the greater.

MM.30
2.3 In addition to the equipment required by paragraph 2.2, the normal equipment of every rigid rescue boat shall include:

MM.30.1 – 30.2 – 30.3
.1 A boat-hook;
.2 A bucket;
.3 A knife or hatchet.

MM.31
2.4 In addition to the equipment required by paragraph 2.2 the normal equipment of every inflated rescue boat shall consist of:

MM.31.1 – 31.2 – 31.3 – 31.5 – 31.6
.1 A buoyant safety knife;
.2 Two sponges;
.3 An efficient manually operated bellows or pump;
.4 A repair kit in a suitable container for repairing punctures;
.5 A safety boat-hook.

MM.32 It should be confirmed that the all survival craft is fitted with equipment as detailed above.

5.39 NN. Survival Craft Launching and Embarkation Arrangements

NN.1 Emergency power lighting and general alarm to be examined on emergency power, and verified satisfactory. General alarm audibility in all parts of the vessel to be verified.

NN.2 Verify the means of preventing discharge of water in the lifeboats, and confirm found satisfactory. Remote operated valves to be tested, labelling to be confirmed in order.

NN.3 Illumination of survival craft stowage and launching positions to be verified satisfactory.

NN.4 Lifelines on davit spans and bowsing tackles to be examined and confirmed in order.

NN.5 Lifeboat embarkation ladders to be examined and confirmed in order. Embarkation ladders should be placed in the overboard position, length and attachment to the deck checked, condition of side ropes and steps to be examined.

NN.6 Abandon ship audible signals, PA, alarm bells and ships whistle, to be tested and confirmed satisfactory and audible in all parts of the ship.

NN.7 An operative test of all emergency power supplies to be carried out, lighting and general alarm to be tested and to be confirmed satisfactory.

NN.8 All embarkation arrangements and launching gear to be examined as far as practicable and to be confirmed in satisfactory condition.

NN.9 To be confirmed that the symbols as required are posted throughout the ship.

NN.10 Two way radio communication system to be tested and to be confirmed satisfactory. Lifesaving appliance two way VHF radio telephone apparatus, radar trans-ponders together with their stowage arrangements to be tested and confirmed satisfactory.

NN.11 Appropriate lifeboat launching instructions posted at the launching stations, to be checked and confirmed in order.

NN.12 Muster arrangements to be checked and confirmed in order.

5.40 OO. Inflatable Liferafts and Hydrostatic Release Servicing

OO.1 Report details of all the liferafts on board, makers name, serial number, number of persons certified for, last servicing date and the name of the servicing agent

OO.2 Confirm that all liferafts and any associated hydrostatic release gear, have been serviced during the previous twelve month.

OO.3 Examine liferaft stowage arrangements and confirm that proper release is facilitated, which includes float free arrangements, no overhangs, etc.

OO.4 Appropriate liferaft launching instructions posted at the launching stations, to be checked and confirmed in order.

5.41 PP. Liferaft Launching Appliances

PP.1 Embarkation arrangements for inflatable liferafts and where provided the launching arrangements of davit launched liferafts examined and found satisfactory. Figure III.11. This includes, embarkation ladders, liferaft davits and its gear, etc.

PP.2 Report the renewal or reversing date of the liferaft davit falls, in case of renewal report the details of the new fall wire. Liferaft davit falls to be reversed every two and a half years and renewed every five years.



Figure III.11
Liferaft embarkation

5.42 QQ. Lifejackets

QQ.1 Confirm that the total number of lifejackets on board is as shown on the report form 2114 and that each is fitted with a whistle, lanyard and a light, report total number on the checklist. Children's lifejackets and spare lifejackets should be included.

QQ.2 Confirm that each lifejacket was found in good condition.

QQ.3 It has to be confirmed that the lifejackets are stowed in accessible and clearly marked locations, for example passenger, crew cabins, embarkation stations in lifejacket containers.

QQ.4 When inflatable lifejackets are fitted the servicing date is to be reported.

QQ.5 Confirm that each lifejackets is fitted with retro reflective tape and that the tape is in good condition.

5.43 RR. Lifebuoys, Immersion Suits and Thermal Protective Aids

RR.1 Lifebuoys.

RR.1.1 All lifebuoys are in good condition, are complete in number as shown on form 2114.

RR.1.2 All lifebuoys are of highly visible colour, fitted with beckets and readily available.

RR.1.3 All lifebuoys are marked with name and port of registry in block letters.

RR.1.4 Lifebuoys are fitted with lines, lights and smoke signals as shown on form 2114.

RR1.5 All lifebuoys capable of being rapidly cast loose.

RR.1.6 All lifebuoys fitted with retro- reflective material, in good condition.

RR.2 Immersion suits and thermal protective aids, confirmed complete as shown on form 2114, all found in good condition. This includes TPA's stowed in survival craft as equipment.

5.44 SS. Certified Lifeboat Men

SS.1 A sufficient number of lifeboat men should be on board to satisfy the flag state requirements.

SS.2 Confirm that an engineer has been assigned to each motorised survival craft.

SS.3 Confirm that instructions are available on board for manning of the survival craft which are to be properly supervised.

5.45 TT. Emergency Lights

TT.1 Confirmation is required that all emergency lights have been tested and found in order.

TT.2 For ro-ro passenger ships, confirm that supplementary emergency lights have been tested and found in order.

TT.3 Necessary spare bulbs for the emergency lights should be confirmed on board.

5.46 UU. Safety of Navigation

UU.1 Ship-borne navigation equipment.
SOLAS V, Regulation 12
(i) Ships of 150 tons gross tonnage and upwards shall be fitted with:

UU.3
1. A standard magnetic compass, except as provided in subparagraph (iv);
2. A steering magnetic compass, unless heading information provided by the standard compass required under (1) is made available and is clearly readable by the helmsman at the main steering position;

UU.5
3. Adequate means of communication between the standard compass position and the normal navigation control position to the satisfaction of the Administration; and
4. Means for taking bearings as nearly as practicable over an arc of the horizon of 360°.

UU.13
(ii) Each magnetic compass referred to in subparagraph (i) shall be properly adjusted, residual deviations shall be available at all times.

UU.3
(iii) A spare magnetic compass, interchangeable with the standard compass, shall be carried, unless the steering compass mentioned in subparagraph (i)(2) or a gyro-compass is fitted.
(iv) The Administration, if it considers it unreasonable or unnecessary to require a standard magnetic compass, may exempt individual ships or classes of ships from these requirements if the nature of the voyage, the ship's proximity to land or the type of ship does not warrant a standard compass, provided that a suitable steering compass is in all cases carried.

UU.1
(d) Ships of 500 tons gross tonnage and upwards constructed on or after 1 September 1984 shall be fitted with a gyro-compass complying with the following requirements:
(i) The master gyro-compass or a gyro repeater shall be clearly readable by the helmsman at the main steering position;
(ii) On ships of 1,600 tons gross tonnage and upwards a gyro repeater or gyro repeaters shall be provided and

shall be suitably placed for taking bearings as nearly as practicable over an arc of the horizon of 360°.

(e) Ships of 1,600 tons gross tonnage and upwards, constructed before 1 September 1984, when engaged on international voyages, shall be fitted with a gyro-compass complying with the requirements of paragraph (d).

UU.10

(f) Ships with emergency steering positions shall at least be provided with a telephone or other means of communication for relaying heading information to such positions. In addition, ships of 500 tons gross tonnage and upwards constructed on or after 1 February 1992 shall be provided with arrangements for supplying visual compass readings to the emergency steering position.

UU.11

(g) Ships of 500 tons gross tonnage and upwards constructed on or after 1 September 1984 and ships of 1,600 tons gross tonnage and upwards constructed before 1 September 1984 shall be fitted with a radar installation. From 1 February 1995, the radar installation shall be capable of operating in the 9 GHz frequency band. In addition, after 1 February 1995, passenger ships irrespective of size and cargo ships of 300 tons gross tonnage and upwards when engaged on international voyages shall be fitted with a radar installation capable of operating in the 9 GHz frequency band. Passenger ships of less than 500 tons gross tonnage and cargo ships of 300 tons gross tonnage and upwards but less than 500 tons gross tonnage may be exempted from compliance with the requirements of paragraph (r) at the discretion of the Administration, provided that the equipment is fully compatible with the radar transponder for search and rescue.

(h) Ships of 10,000 tons gross tonnage and upwards shall be fitted with two radar installations, each capable of being operated independently of the other. From 1 February 1995, at least one of the radar installations shall be capable of operating in the 9 GHz frequency band.

(i) Facilities for plotting radar readings shall be provided on the navigating bridge of ships required by paragraph (g) or (h) to be fitted with a radar installation. In ships of 1,600 tons gross tonnage and upwards constructed on or after 1 September 1984 the plotting facilities shall be at least as effective as a reflection plotter.

UU.9

(i) An automatic radar plotting aid shall be fitted on;

1. Ships of 10,000 tons gross tonnage and upwards, constructed on or after 1 September 1984;
2. Tankers constructed before 1 September 1984 as follows:

(aa) If of 40,000 tons gross tonnage and upwards by 1 January 1985;

(bb) If of 10,000 tons gross tonnage and upwards but less than 40,000 tons gross tonnage, by 1 January 1986;

3. Ships constructed before 1 September 1984, that are not tankers, as follows:

(aa) If of 40,000 tons gross tonnage and upwards by 1 September 1986;

(bb) If of 20,000 tons gross tonnage and upwards, but less than 40,000 tons gross tonnage, by 1 September 1987;

(cc) If of 15,000 tons gross tonnage and upwards, but less than 20,000 tons gross tonnage, by 1 September 1988.

(ii) Automatic radar plotting aids fitted prior to 1 September 1984 which do not fully conform to the performance standards adopted by the Organization may, at the discretion of the Administration, be retained until 1 January 1991.

(iii) The Administration may exempt ships from the requirements of this paragraph, in cases where it considers it unreasonable or unnecessary for such equipment to be carried, or when the ships will be taken permanently out of service within two years of the appropriate implementation date.

UU.2

(k) When engaged on international voyages ships of 1,600 tons gross tonnage and upwards constructed before 25 May 1980 and ships of 500 tons gross tonnage and upwards constructed on or after 25 May 1980 shall be fitted with an echo-sounding device.

(l) When engaged on international voyages ships of 500 tons gross tonnage and upwards constructed on or after 1 September 1984 shall be fitted with a device to indicate speed and distance. Ships required by paragraph (j) to be fitted with an automatic radar plotting aid shall be fitted with a device to indicate speed and distance through the water.

UU.4

(m) Ships of 1,600 tons gross tonnage and upwards constructed before 1 September 1984 and all ships of 500 tons gross tonnage and upwards constructed on or after 1 September 1984 shall be fitted with indicators showing the rudder angle, the rate of revolution of each propeller and in addition, if fitted with variable pitch propellers or lateral thrust propellers, the pitch and operational mode of such propellers. All these indicators shall be readable from the conning position.

UU.4

(n) Ships of 100,000 tons gross tonnage and upwards constructed on or after 1 September 1984 shall be fitted with a rate-of-turn indicator.

(o) Except as provided in regulations I/7(b)(ii), I/8 and I/9, while all reasonable steps shall be taken to maintain the apparatus referred to in paragraphs (d) to (n) in efficient working order, malfunctions of the equipment shall not be considered as making a ship un-seaworthy or as a reason for delaying the ship in ports where repair facilities are not readily available.

UU.12

(p) When engaged on international voyages, ships of 1,600 tons gross tonnage and upwards shall be fitted with a radio direction-finding apparatus. The Administration may exempt a ship from this requirement if it considers it unreasonable or unnecessary for such apparatus to be carried or if the ship is provided with

other radio navigation equipment suitable for use throughout its intended voyages.

(q) Until 1 February 1999, ships of 1,600 tons gross tonnage and upwards constructed on or after 25 May 1980 and before 1 February 1995, when engaged on international voyages, shall be fitted with radio equipment for homing on the radiotelephone distress frequency.

UU.6 Auto-pilot to be confirmed operational

UU.7 Verify that auto-pilot change over instructions are posted in the wheel-house.

SOLAS 1974 Chapter V, Safety of Navigation, Regulation 12, Shipborne Navigation Equipment

	Reg. 12 Para number	>550 but <1600	>1600 but <10000	>10000 but <15000	>15000 but <100000	>100000	Remarks	See*
Standard magnetic compass	(b)(i)(1)	A	A	A	A	A	See Note 2	F
Steering magnetic compass	(b)(i)(2)	A	A	A	A	A	See Note 1	E, F
Means of communicating between standard compass position and normal navigation control position	(b)(i)(3)	A	A	A	A	A	-	F
Means of taking bearing through 360 degrees.	(b)(i)(4)	A	A	A	A	A	–	E, F
Magnetic compass table or curve of residual deviations	(b)(ii)	A	A	A	A	A	–	
Spare magnetic compass	(b)(iii)	A	A	A	A	A	See Note 3	F
Gyro compass	(d) (e)	B	A	A	A	A	See Note 4	
Heading information	(f)	A	A	A	A	A	See Note 8	
Radar (one or two)	(g) (h)	B (1)	A (1)	A (2)	A (2)	A (2)	See Note 5	G
Radar plotting facilities	(i)	B	A	A	A	A	See Note 6	
Automatic radar plotting aid tankers	(i)	–		A	A	A	–	
Automatic radar plotting aid others	–	–		B	A	A	–	
Echo sounder	(k)	C	A	A	A	A	–	
Speed and distance indicator tankers	(l)	B	B	A	A	A	–	
Speed and distance indicator others	–	B	B	B	A	A	–	
Rudder angle indicator	(m)	B	A	A	A	A	See Note 7	
Propeller revolution counter	(m)	B	A	A	A	A	See Note 7	
Propeller pitch and mode indicator	(m)	B	A	A	A	A	See Note 7	
Rate of turn indicator	(n)	–	–	–	–	B	–	
Radio direction finder	(p)	–	A	A	A	A	See Note 9	
Homing on 2182 kHz	(q)	–	D	D	D	D	–	

***Key**

A = Required on any ship regardless of date of construction
B = Required on ships constructed on or after 1st September 1984
C = Required on ships constructed on or after 25th May 1980
D = Required on ships constructed on or after 25th May 1980 and before 1st February 1995
E = Require on ships < 150 gross tons
F = Required on ships > 150 but < 500 gross tons
G = One required on ships > 300 gross tons after 1st February 1995

Notes

1. Is require unless heading information provided by the standard compass (if fitted, see note 2)is made available and is clearly readable by the helmsman at the main steering position.
2. Exemption may be granted from this requirement providing that in all cases a suitable steering compass is carried and the Administration considers the provision of the standard compass unreasonable or unnecessary, having taken into account the nature of the voyage, the ship's proximity to land or the type of the ship.
3. Required and to be interchangeable with the standard compass unless a steering compass or gyro compass is fitted.
4. The master gyro compass or gyro repeater shall be clearly readable by the helmsman at the main steering position. Additionally, on ships of 1600 gross tons and upwards, a gyro repeater shall be suitably placed for taking bearings as nearly as practicable over an arc of the horizon of 360 degrees.
5. From the 1st February 1995 at least one radar installation shall be capable of operating in the 9 GHz frequency band. Where two radars are fitted they are to be operationally independent of each other.
6. Radar plotting facilities on vessels of 1600 gross tons and upwards are to be at least as effective as a reflection plotter.
7. Indicators which can be read at the conning position are required to be fitted.
8. Heading information is required to be provided at the emergency steering position on all ships fitted with such a position and for ships constructed after 1st February 1992, there are also to be arrangements to supply visual compass readings.
9. The Administration may exempt a ship from this requirement.

5.47 VV. Signalling Apparatus and International Collision Regulations

VV.1 Daylight signalling lamp and source of power. The daylight signalling lamp is to be tested to ensure it is operating satisfactorily on both mains and emergency supply.

VV.2 Forecastle bell.

VV.3 Gong.

VV.4 Ship's whistles.

Bells and gongs are to be examined for excessive corrosion and tested to ensure they continue to give a clear sound.

A bell or gong, produce a sound pressure level of not less than 110 dB at a distance of 1 metre from it.

The ship's whistles are to be tested for sound and satisfactory operation. If only one electric whistle is provided, this is to be tested on both the main and emergency supply.

If whistles are fitted at a distance apart of more than 100 metres, it should be so arranged that they are not sounded simultaneously.

The fundamental frequency of the whistle signal shall lie within the range 70-700 Hz.

VV.5 Three black ball shapes to be verified in good condition.

VV.6 One black diamond shape to be verified in good condition.

VV.7 Cylindrical shape to be verified in good condition.

5.48 WW. Navigation Lights

WW.1 Confirm that the sidelights inboard screens are painted matt black.

WW.2 Confirm that the navigation lights are in good condition and operating satisfactorily.

WW.3 Confirm that the navigation light failure warning device, visual audible on the bridge operating efficiently. Navigation light indicators and warning to be tested.

5.49 XX. Bridge Distress Signals

XX.1 Indicate expiry or manufacture date of the line throwing rockets.

XX.2 Indicate expiry or manufacture date of the igniter cartridges (if applicable) of the line throwing appliances. Figure III.12.

Every vessel is required to carry 4 line throwing appliances. These may be either, self contained units with lines, cartridges, lines and rockets in one container, or 4 sets of pistol fired rockets, with separate lines.

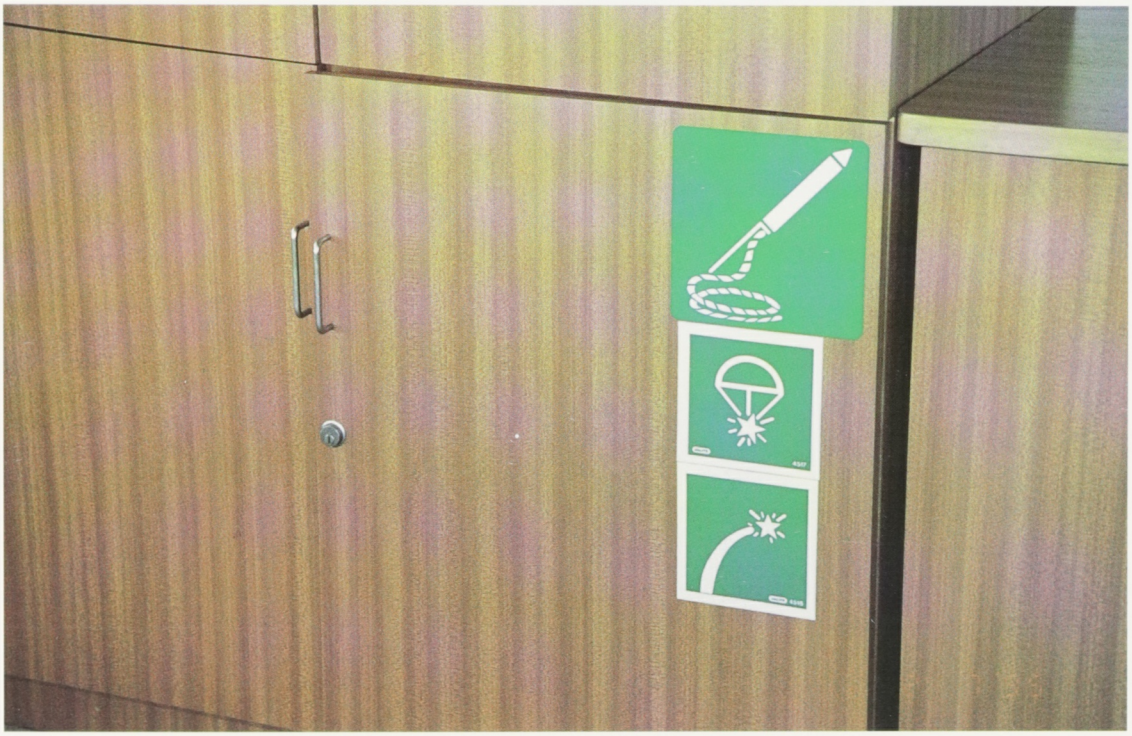


Figure III.12
Storage location for distress equipment

XX.3 Indicate expiry or manufacture date of the 12 red parachute signals.

Only 12 red parachute signals need to be carried

XX.4 Line throwing rockets, cartridges and ships distress flares found in satisfactory condition. Pyrotechnic signals on board and in lifeboats, including rockets and cartridges are to be renewed on or before the date of expiry or within three years of the date of manufacture unless there is a specific national requirement.

Pyrotechnics which can be seen to have deteriorated due to damp or mechanical damage are to be renewed immediately.

5.50 YY. Musters and Drills

YY.1 Confirm fire satisfactory drill carried out. Fire drill should be observed, to determine the satisfactory functioning of the equipment. The performance of the crew should be witnessed and reported on for Bahamian flag ships only. Figure III.13.

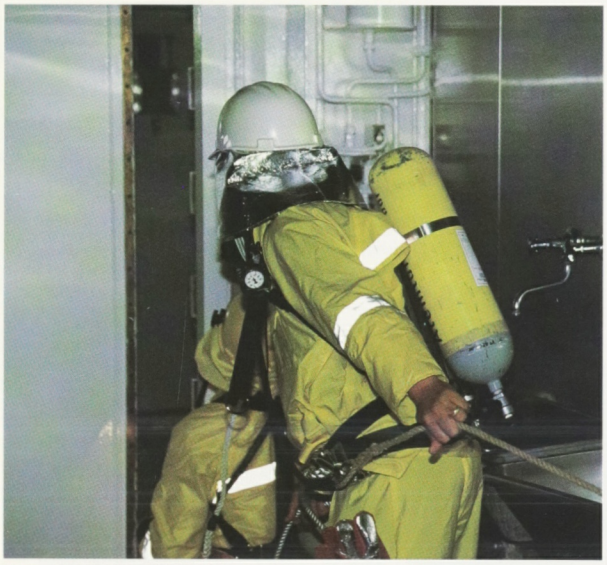


Figure III.13
Fire drill

YY.2 Confirm that a realistic crew muster and lifeboat drill carried out.

5.51 ZZ. Pilot Ladders

ZZ.1 Pilot ladder side ropes and steps in good condition.

ZZ.2 The condition and illumination of the pilot ladder and boarding position found in order.

ZZ.3 A heaving line and one of the lifebuoys with self-igniting light readily to hand.

ZZ.4 Pilot ladder(s) and accommodation ladder(s) found to be in good condition.

ZZ.5 Pilot ladder(s) and accommodation ladder(s) raised and examined in position.

Note:

An accommodation ladder is a survey-able item only, when the distance from sea level to the point of access to, or egress from, the ship exceeds 9 m, and when it is intended to embark and disembark pilots by means of the accommodation ladder.

5.52 AAA. Mechanical Pilot Hoist

AAA.1 Mechanical pilot hoist rigged, examined under working condition and found satisfactory.

AAA.2 Mechanical pilot hoist found in satisfactory condition and operational.

Appendix A
Schedule and remarks of the Passenger Ship Safety Survey

MV. CRUISE SHIP
ISSUE 8 – 15-APRIL-94

Annual surveys schedule and remarks.
Surveys to be carried out are, Passenger Ship Safety Survey, Annual Hull Survey, Periodical Loadline Inspection, Marpol Annual Survey, Continuous Machinery, Continuous Hull, Elevator Survey.

Schedule and Remarks:

Friday 08 April 94
Lifeboat inventory of port side lifeboats and starboard lifeboats no 21, 19, 17, 15, 11, 9 examined.
Remarks, windscreen wiper blades on boats 10, 12, 18, 19, 21, 11 and 9 to be renewed. No. 18 boat food locker sealing ring to renew. Drain all the lifeboats.

Saturday 09 April 94
Starboard side lifeboats launched.
Outside deck fire dampers tested.
Lifebuoys examined.
Watertight doors operated from the wheelhouse.
PA system and alarm system partially tested.
Lifeboat inventory examination starboard side completed.
Engine room equipment to examined as follows;
Steering gear tested, emergency generator tested, battery discharge tests to be repeated.
Bulkhead valves, fuel tank remote valve closing, bilge valves, oil pump remote stops, tested.
Remarks, davit brakes of no. 3 and no. 21 lifeboats to adjust, starting battery of boat no. 19 to recharge, speakers in galley and stairway 65 to check, other speakers to check for volume.

Sunday 10 April 94
Sprinkler stations flow switches tested.
All internal accommodation fire dampers tested.
Fire mans out fits, open deck fire stations checked.
Oily water separator and 15 ppm alarm tested.
Fire pumps, bilge pumps, sprinkler pumps tested.
Part of the fire screen doors tested.

Monday 11 April 94
Port lifeboats launched.
Accommodation fire stations examined, fire main examined.
Accommodation fan stops tested.
Halon system serviced.
Continuous hull items examined, 8207, 8215, 8223, 8231, 8248, 8256, 8264, 8272, 8280, 5424, 5432, 5440, 5457, 5465, 5473, 5481, 5498, 5504, 5512, 5520, 7775, 7792, 7807.
Battery drain test carried out.
Machinery spaces fan stops and ventilator fire dampers tested.
Remarks, Lifeboat brakes to adjust, no. 10, 12, 14 and 18.
Fire screen doors bridge indicator lights checked.

Tuesday 12 April 94
Fire screen doors tested locally completed. Main and crew galley uptakes checked.
Smoke detection system and break glass alarms tested except engine room and engine casing.
Navigation equipment examined.
Remarks, main galley two uptakes to clean.
FSD to repairs as follows, 919, 1012, 1017, 1018.
Smoke detectors to repair as follows,2-139 cabin 551, 2-158 ER control room, 3-124 Halon control space, 3-118 cabin 167, R-69 stairs 0, M-88 AC room 3, U-79 cabin 88, E-64 cabin 143, A 52 AC room aft ctr, P-30 port aft sapphire launch, L-5 lobby stairs 215, V-5 lobby stairs 215, V-14 aft port and stbd ER air intakes, S-5 lobby stairs 215.
Battery of lifeboat 19 replaced and engine started.

Wednesday 13 April 94
Emergency light system checked.
Water tight doors from bulk head deck and locally operated.
Fire hoses tested. Lifejackets checked.
Commencement of elevator examination. Elevators 16, 17, 18, 10, 9, 8 and 15 examined.
Continuous hull items examined as follows, items 5600, 5617, 5705, 5738, 6900, 6933, 7382, 7413, 6961, 6994, 6451, 6484, 7825. heeling tank no. 3 and 4, painting in tanks is deteriorated.
Completion of smoke detector and break glass alarm test.
Smoke detector 0-173 propulsion room centre to repair.
Lifeboat winch brake no 3 and 21 tested and found good.
Main galley uptake cleaned.
Emergency escape routes should be kept clear of obstructions, found that brooms dust pans and other cleaning tools are stored in such spaces, furthermore the engine room escape leading to the starboard marshalling area has a set of shelves fitted over the hatch, this should be removed.

Thursday 14 April 94
Elevator examination completed.
Load line items examined. Draft stops examined.
Continuous hull items, following examined and found satisfactory: 6427, 6636, 6660, 6990, 7028, 7085, 7173, 8297, 8303, 8311, 8328, 8336, 8344, 5578, 5586, 5762, 5344, 5352, 5360, 5377, 5385, 5393, 5408, 5416, 6066, 6090, 6121, 6757, 6781, 6812, 7116, 7140, 7153, 7204, 7237, 7261, 7294, 7671, 7784, 7818.
Megger test results to be verified.
Continuous machinery items, following items credited: 2082, 2132, 3078, 3111, 3128, 3209, 3216, 3278, 4088, 4402, 4419.
Smoke detectors requiring repairs now found repaired and tested.
FSD no. 919, 1012, 1017 and 1018 tested after repairs.
Remarks, elevator cab hoisting and counter weight cables of following elevators, no. 7, 8, 9, 10, 11, 14, 17 and 18, start to wear at the outer strands of the cables, pulley grooves dimensions and wear may be investigated. Cables should be kept under observation for further wear. No. 11-elevator safety wire tensioning weight to free, door switch spring to

renew. No. 3 elevator pit emergency stop to repair, open button in cab to repair. No. 1 elevator split pin in counter weight wedge mechanism to replace, inner door to adjust. No. 5 elevator escape door of cab to repair, counter weight wedge mechanism split pin to replace, indicator for no. 10 deck to repair. No. 7 does no go to the Lido deck. No. 6 elevator under repair and remains to be examined. No. 12 elevator hydraulic pipes in the pit and indoors ramp top seals are leaking. No. 13 elevator escape hatch door limit switch to repair. Elevator counter weight hydraulic ground stop attachments to be checked.

Friday 15 April 94

Paper work, documentation.

Radio inspection. Ventilation dampers and fan stops in engine room tested.

Checked brakes of port lifeboats no. 10, 12, 14 and 18, port rescue boat launched.

Completed test of PA system, remarks, sound level of following spaces to be improved: Empress deck aft, deck 3 aft, stairway 65, corridor deck 3 centre, main laundry deck 2, refrigerated compressor room in engine room.

Machinery spaces fire damper controls no M31201, M31202, M41117, M 30211, M301111, M31106, and M31103, to be checked.

FAN ROOMS AND AC ROOMS SHOULD NOT BE USED AS STOREROOMS, WHEN IT IS NECESSARY TO STORE A LIMITED AMOUNT OF EQUIPMENT IN THOSE SPACES, THIS EQUIPMENT SHOULD BE NON COMBUSTIBLE AND STOWED IN A SAFE MANNER, TO AVOID DAMAGE TO THE VENTILATION SYSTEMS.

KEEP ACCESS TO SPRINKLER STATIONS AND FIRE SCREEN DOORS FREE AT ALL TIMES.

Appendix B
Masters Questionnaire

Questionnaire for the vessel's master regarding data required for the survey and its reporting.

Question	Dealt with
Liferaft and latest servicing particulars, this including date of the hydrostatic release gear servicing.	
Lifeboat and liferaft davits falls, reversing date, or date when falls were renewed, copy of new wire certificate.	
Expire or manufacture date of the vessels and lifeboat pyrotechnics, Ship, 4 Line throwing appliances, cartridges: 12 Parachute signals: Lifeboat pyrotechnics, 2 Smoke signals: 4 Parachute signals: 6 Red flares:	
Details and certificate of the servicing of the fixed fire fighting installation.	
Details and certificate of the servicing of the portable and non-portable fire extinguishers.	
Copy of the results of the megger test of 20% of the vessel's electrical installation.	
Compass and RDF calibration date or records of check bearing taken.	
A/Amax percentage of compliance.	
The date of the last full muster of passengers and crew for boat and fire drill is the date prior to your survey and shall be recorded on the checklist.	
Confirmation that at that occasion the equipment of the lifeboats was examined and found in order.	
Confirmation that the master is aware of SOLAS II-2 Reg. 21 availability of fire extinguishers.	
Confirmation that the watertight doors are closed at sea, when exempt, copy of the exemption certificate.	
Copy of the vessels safe manning certificate, Bahamian flag vessels only.	
Report of any fire taken place on board in the past year.	